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Tetsuka et al.

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(45) **Date of Patent: Apr. 26, 2016**

(54) **PEDALING FORCE MEASUREMENT DEVICE**

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G01L 1/22 (2006.01)
G01L 3/24 (2006.01)
G01L 5/16 (2006.01)

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CPC . ***G01L 1/22*** (2013.01); ***G01L 3/247*** (2013.01); ***G01L 5/16*** (2013.01)

(58) **Field of Classification Search**
CPC G01L 1/04; G01L 1/22; G01L 1/2231
USPC 73/862.627
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,463,433	A	7/1984	Hull et al.	
5,027,303	A	6/1991	Witte	
6,340,067	B1	1/2002	Fujiwara et al.	
6,418,797	B1 *	7/2002	Ambrosina	B62M 6/40 73/862.29
7,861,599	B2	1/2011	Meggiolan	
8,065,926	B2	11/2011	Meyer	
8,387,470	B2 *	3/2013	Tuulari	G01L 1/2237 73/862.627
8,584,529	B2 *	11/2013	Fisher	B62M 3/00 73/760
8,800,389	B2 *	8/2014	Tetsuka	B62M 3/00 73/862
8,881,608	B2 *	11/2014	Tetsuka	B62M 3/16 73/862

(Continued)

FOREIGN PATENT DOCUMENTS

CN	1442680 A	9/2003
CN	101279629 A	10/2008
DE	44 35 174 A1	3/1996

(Continued)

Primary Examiner — Lisa Caputo
Assistant Examiner — Octavia Hollington
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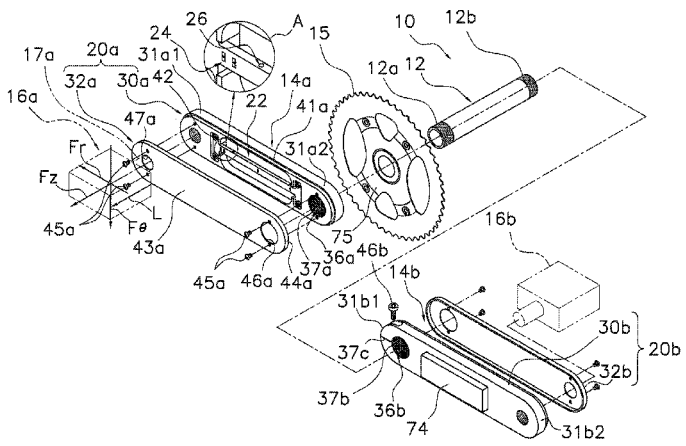
(57) **ABSTRACT**

A first pedaling force measurement device measures a plurality of pedaling force parameters acting on a first crank arm to one end of which a first pedal can be attached and to another end of which a crank shaft can be attached. The first pedaling force measurement device is provided with a strain-flexing part, a first parameter detection part and a first interference suppression part. Strain acting on the first crank arm is conveyed to the strain-flexing part. The parameter detection part is disposed on the strain-flexing part, and detects a plurality of parameters based on the strain being conveyed to the strain-flexing part. The interference suppression part suppresses interference in one parameter detected by the parameter detection part from the other parameters.

23 Claims, 14 Drawing Sheets



(56) **References Cited**

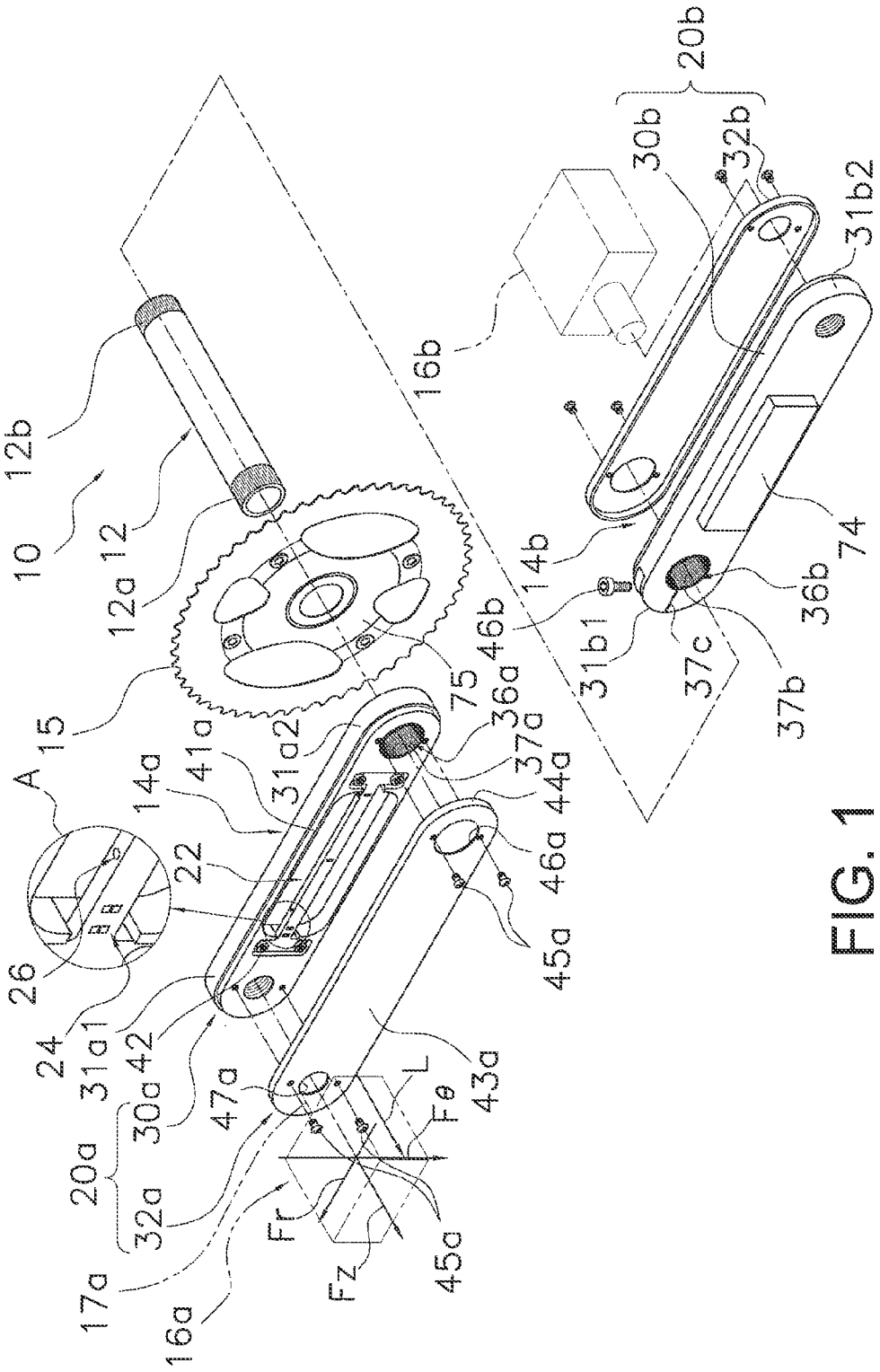
U.S. PATENT DOCUMENTS

2010/0093494	A1*	4/2010	Smith	B62M 6/50 482/8
2010/0263468	A1	10/2010	Fisher et al.	

FOREIGN PATENT DOCUMENTS

DE	699 35 750	T2	8/2007
DE	10 2009 029 633	A1	3/2011
EP	2058637	A2	5/2009
JP	3047816	U	2/1998
WO	2009/006673	A1	1/2009
WO	2011/030215	A1	3/2011
WO	2011/135972	A1	11/2011
WO	2012/053114	A1	4/2012
WO	2012/056510	A1	5/2012
WO	2012/056522	A1	5/2012
WO	2012/056558	A1	5/2012

* cited by examiner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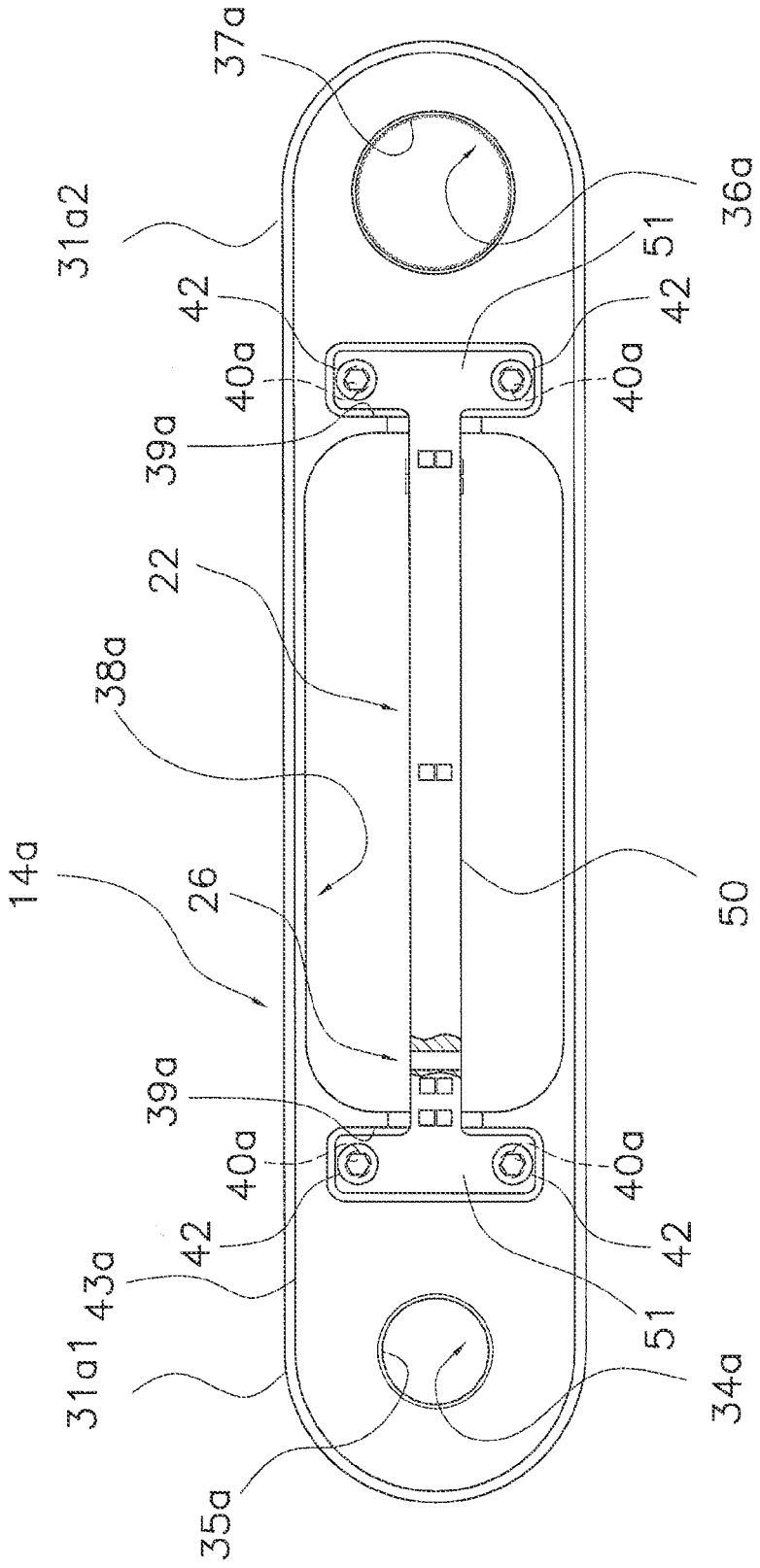
30b
32b
31b2
16b
12b
10
12
12a
14b
31b1
46b
36b
74
37c
37b
15
75
36a
37a
A
41a
31a2
14a
44a
22
46a
45a
26
24
31a1
42
43a
30a
47a
Fθ
L
20a
32a
Fr
Fz
45a
17a
16a

FIG. 1


37a
31a2
36a
42
51
42
40a
40a
39a
22
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43a
51
31a1
34a
35a

FIG. 2

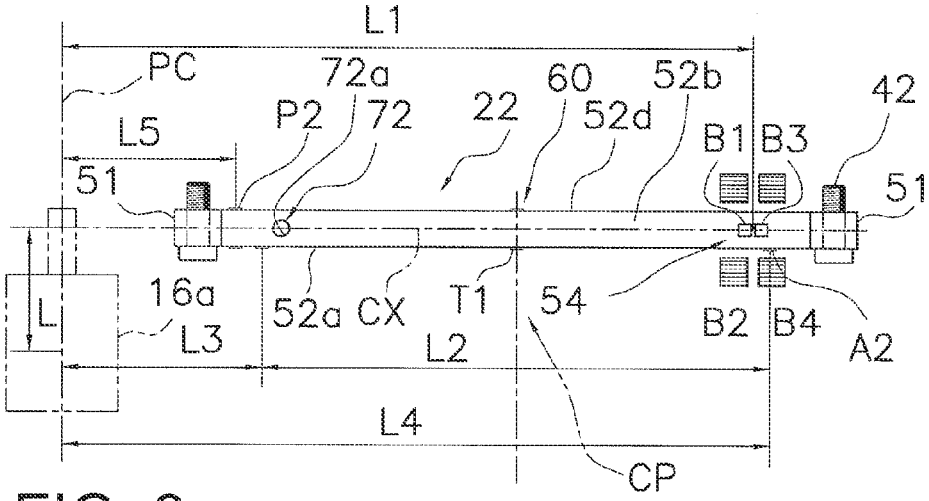

FIG. 3

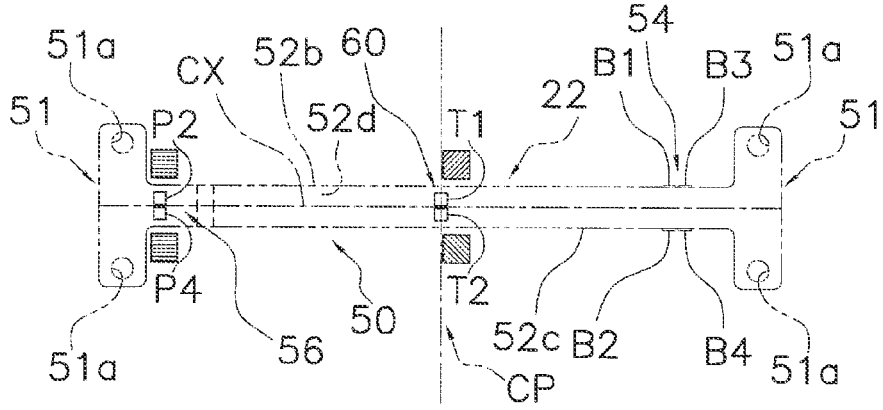

FIG. 4

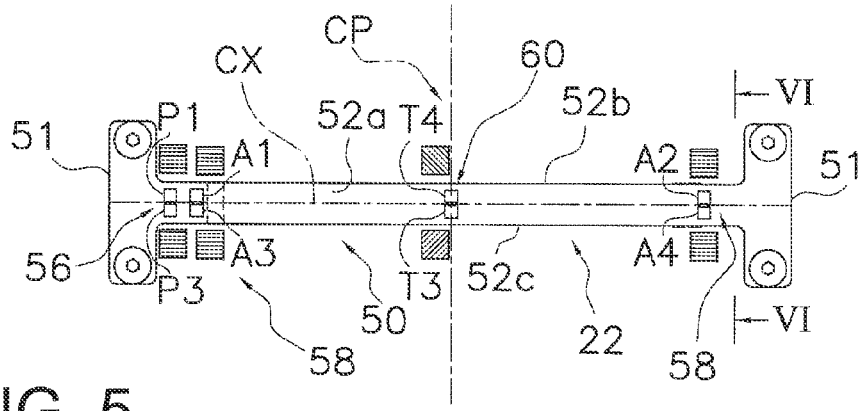

FIG. 5

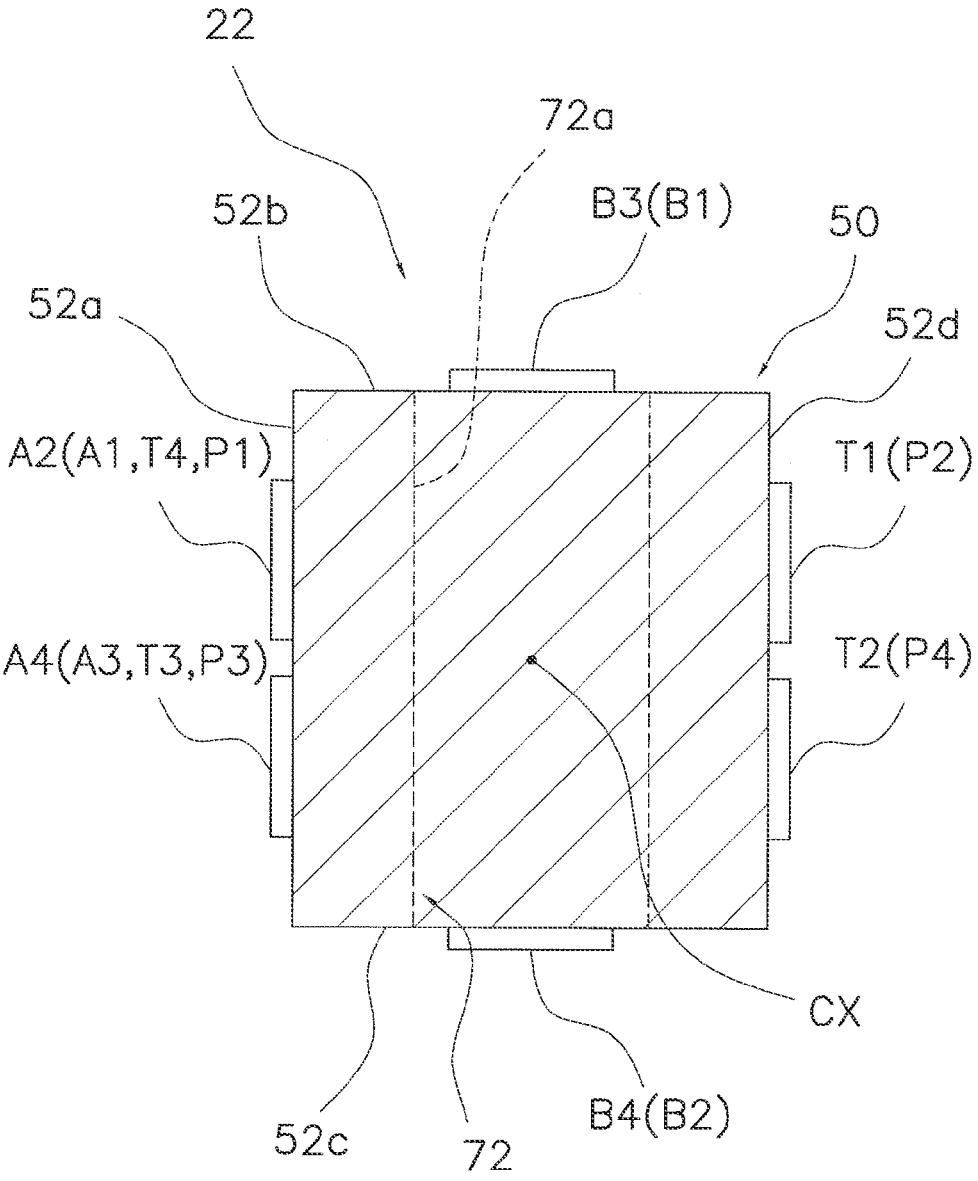
22
72a
52b
B3(B1)
50
52a
52d
A2(A1,T4,P1)
T1(P2)
A4(A3,T3,P3)
T2(P4)
CX
52c
72
B4(B2)

FIG. 6

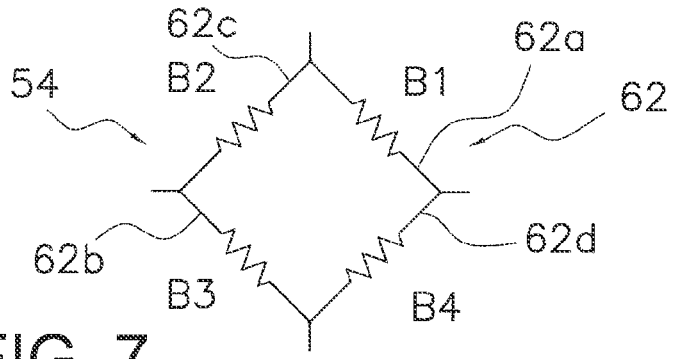

FIG. 7

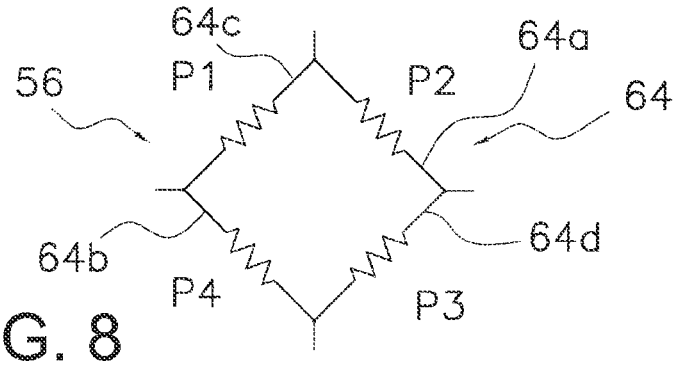

FIG. 8

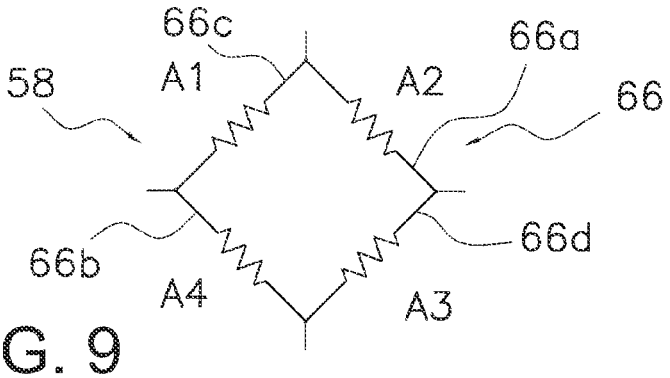

FIG. 9

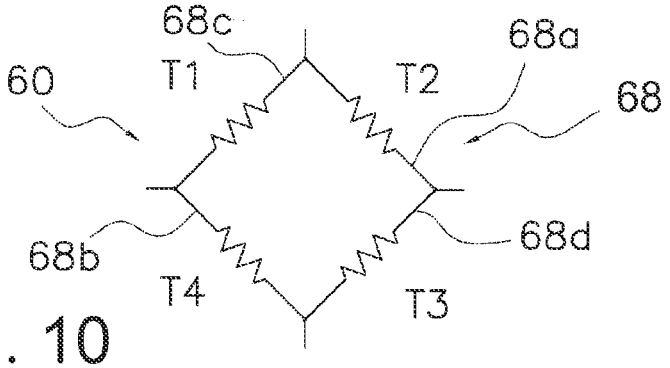

FIG. 10

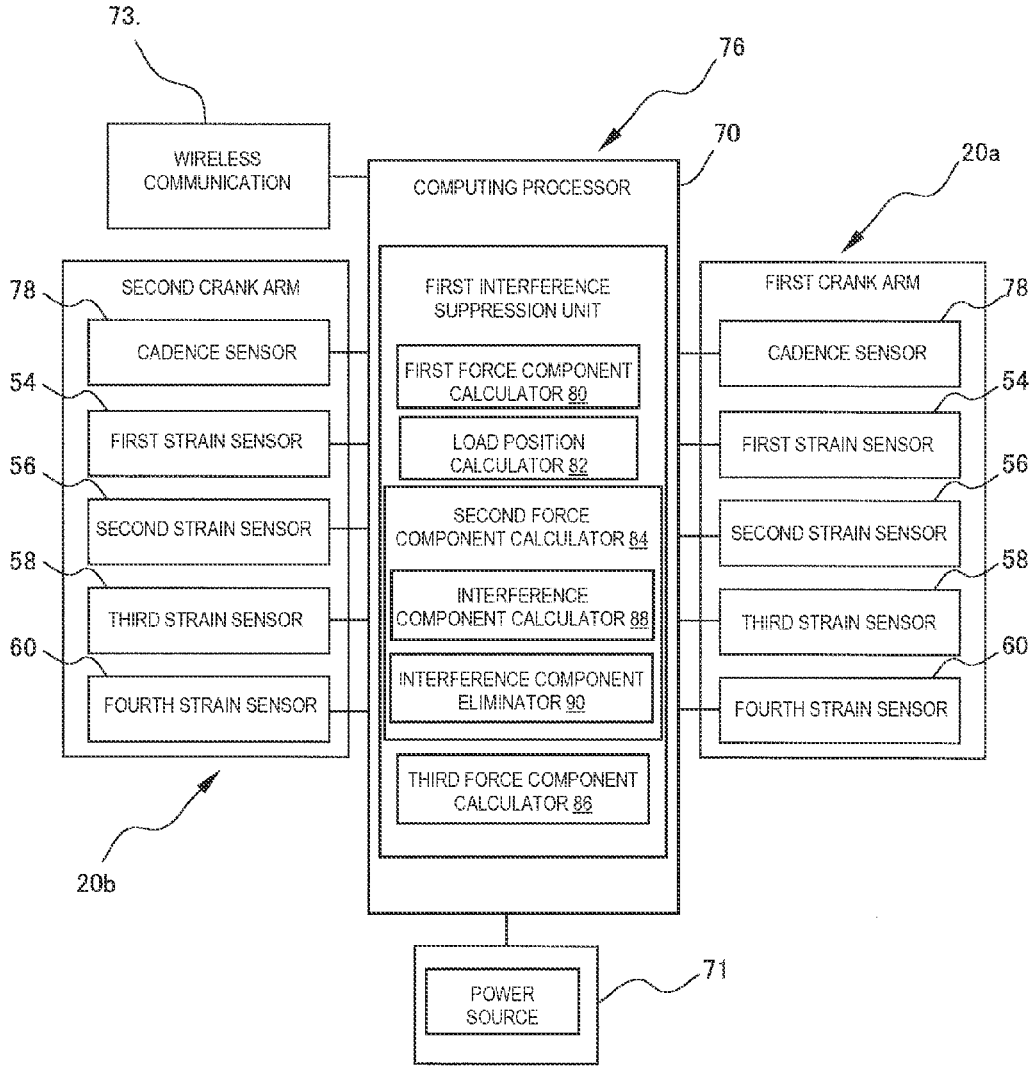
73.
WIRELESS COMMUNICATION
76
70
COMPUTING PROCESSOR
20a
FIRST CRANK ARM
78
CADENCE SENSOR
54
FIRST STRAIN SENSOR
56
SECOND STRAIN SENSOR
58
THIRD STRAIN SENSOR
60
FOURTH STRAIN SENSOR
FIRST INTERFERENCE SUPPRESSION UNIT
FIRST FORCE COMPONENT CALCULATOR 80
LOAD POSITION CALCULATOR 82
SECOND FORCE COMPONENT CALCULATOR 84
INTERFERENCE COMPONENT CALCULATOR 88
INTERFERENCE COMPONENT ELIMINATOR 90
THIRD FORCE COMPONENT CALCULATOR 86
SECOND CRANK ARM
78
CADENCE SENSOR
54
FIRST STRAIN SENSOR
56
SECOND STRAIN SENSOR
58
THIRD STRAIN SENSOR
60
FOURTH STRAIN SENSOR
20b
POWER SOURCE
71

FIG. 11

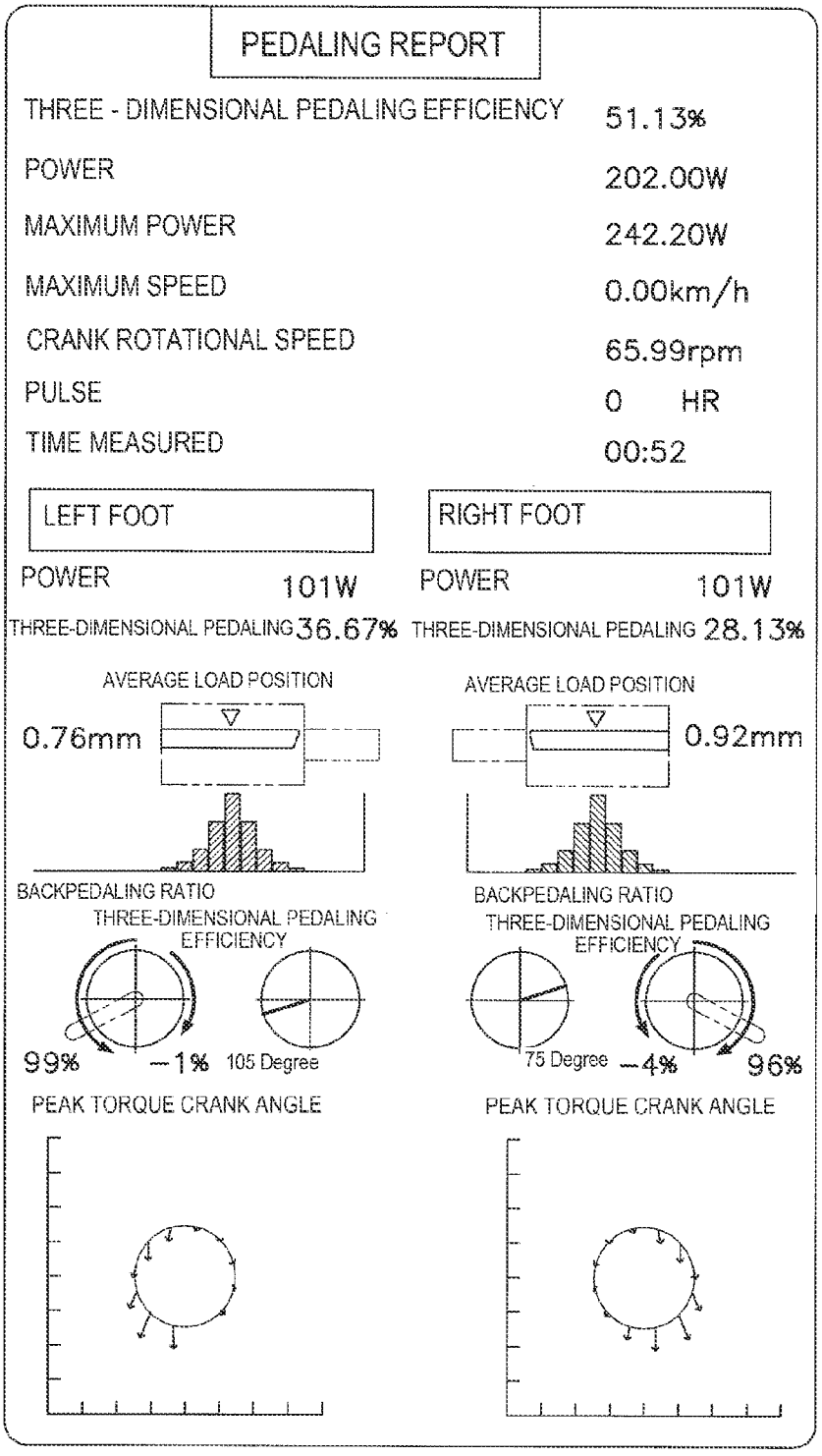
PEDALING REPORT
THREE - DIMENSIONAL PEDALING EFFICIENCY 51.13%
POWER 202.00W
MAXIMUM POWER 242.20W
MAXIMUM SPEED 0.00km/h
CRANK ROTATIONAL SPEED 65.99rpm
PULSE 0 HR
TIME MEASURED 00:52
LEFT FOOT
POWER 101W
THREE-DIMENSIONAL PEDALING 36.67%
AVERAGE LOAD POSITION
0.76mm
BACKPEDALING RATIO
THREE-DIMENSIONAL PEDALING EFFICIENCY
99%
1%
105 Degree
PEAK TORQUE CRANK ANGLE
RIGHT FOOT
POWER 101W
THREE-DIMENSIONAL PEDALING 28.13%
AVERAGE LOAD POSITION
0.92mm
BACKPEDALING RATIO
THREE-DIMENSIONAL PEDALING EFFICIENCY
75 Degree
4%
96%
PEAK TORQUE CRANK ANGLE

FIG. 12

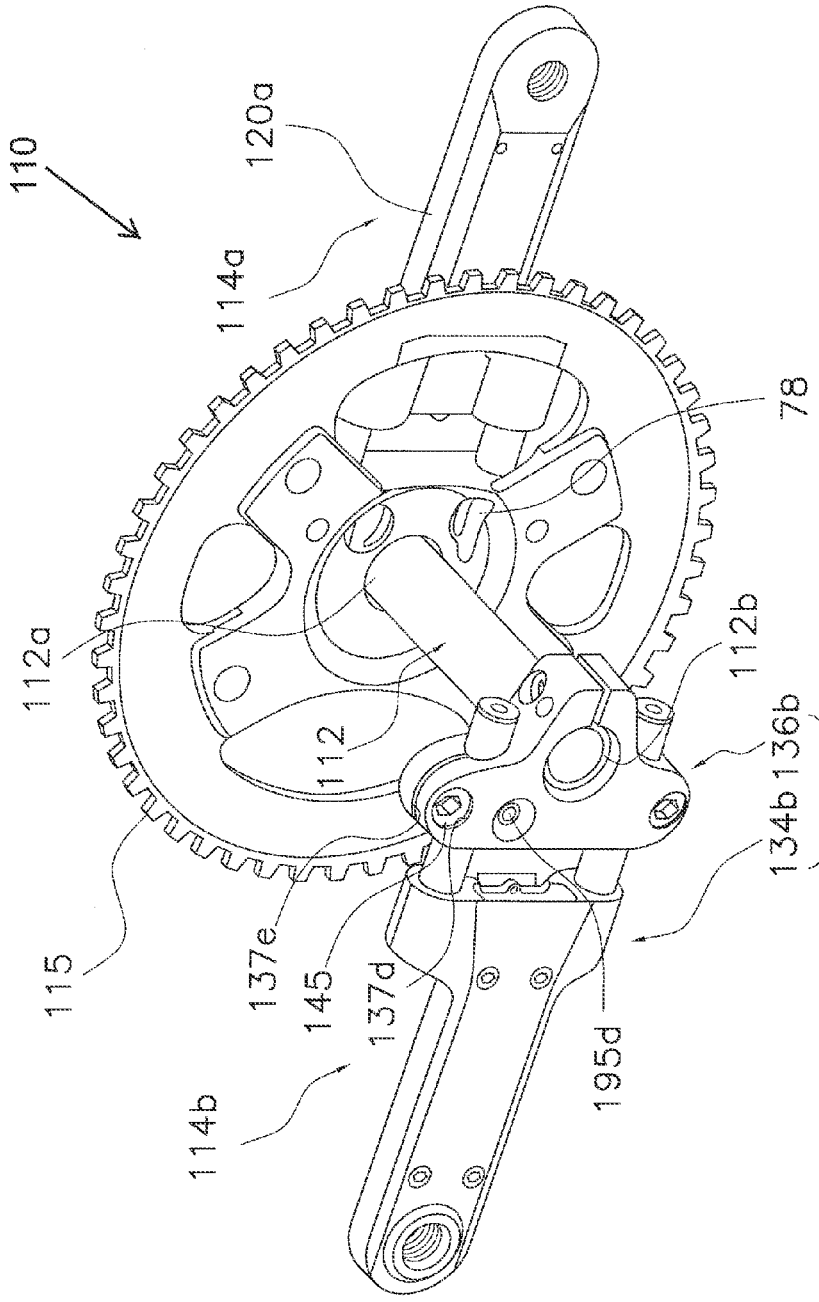
110
120a
114a
78
112a
112
112b
136b
134b
120b
115
137e
145
137d
195d
114b

FIG. 13

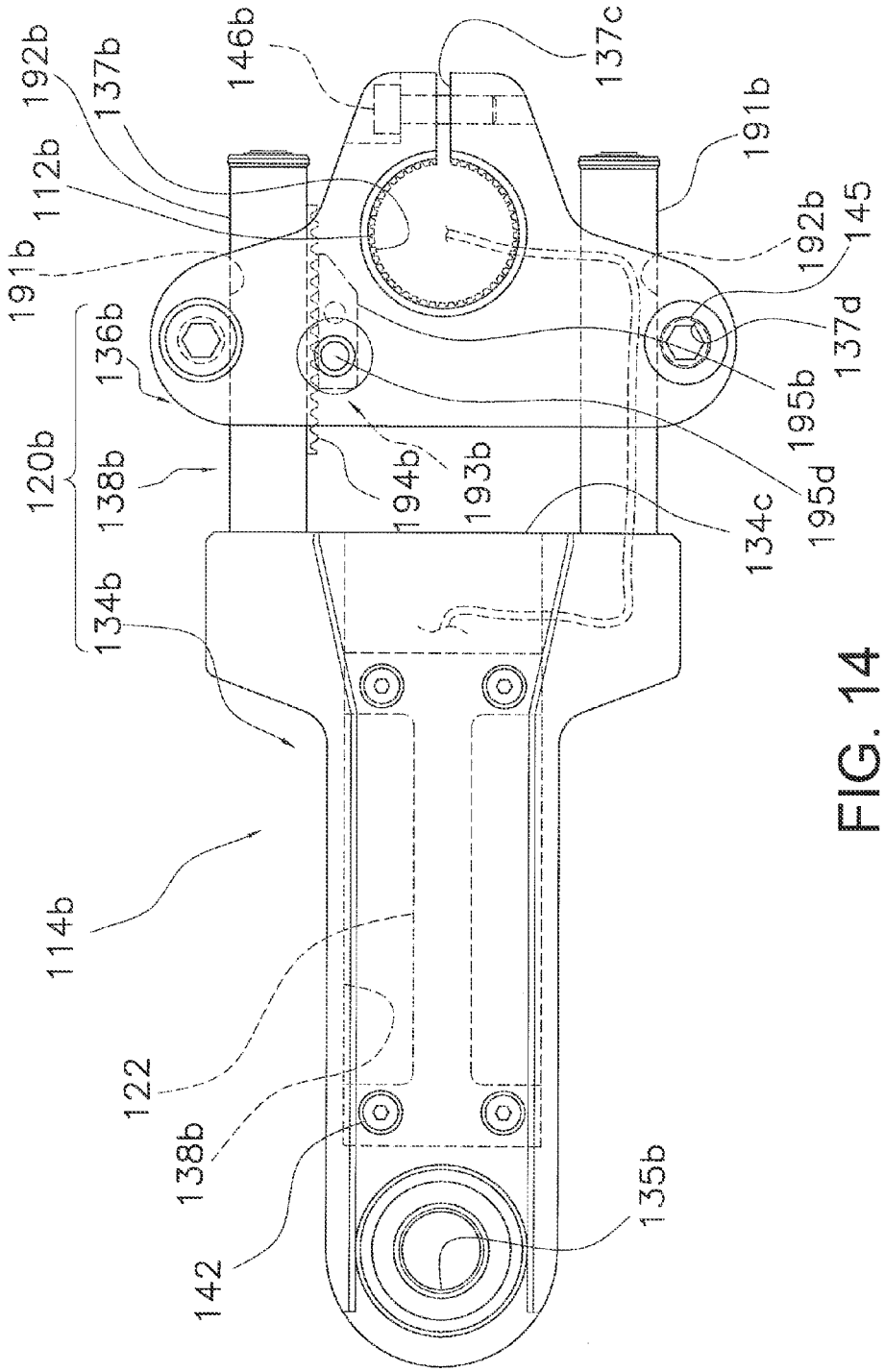
192b
137b
146b
137c
191b
112b
191b
192b
145
136b
137d
195b
120b
138b
194b
193b
195d
134c
134b
114b
122
138b
142
135b

FIG. 14

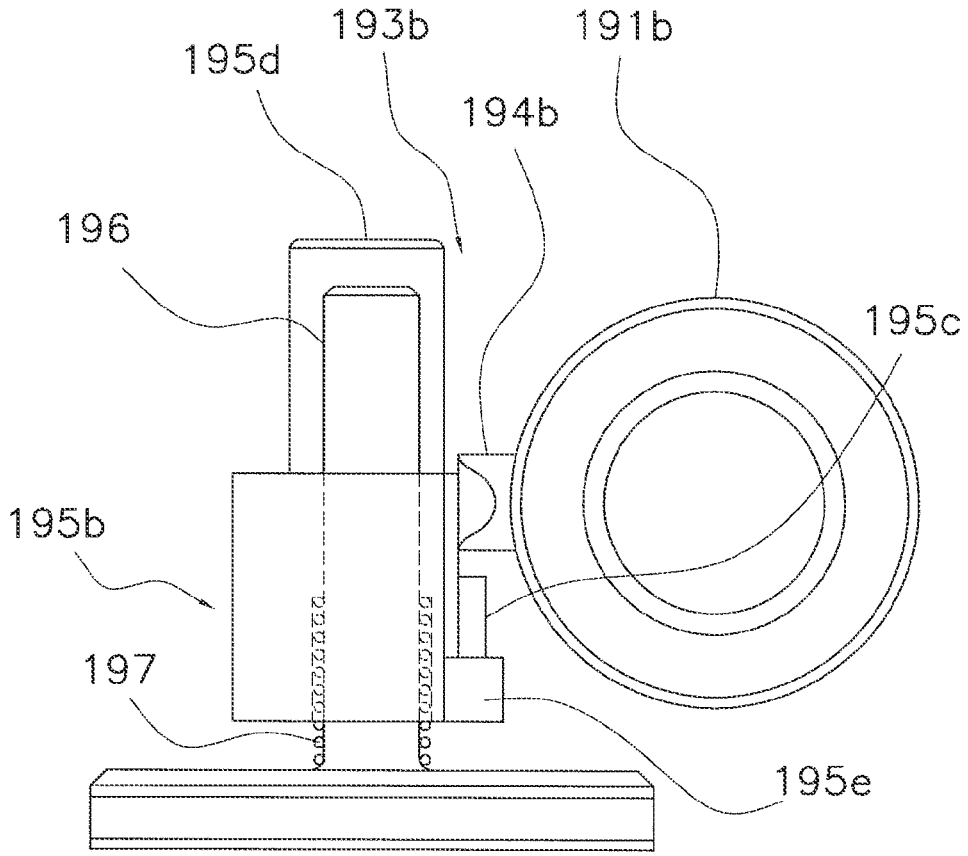

FIG. 15

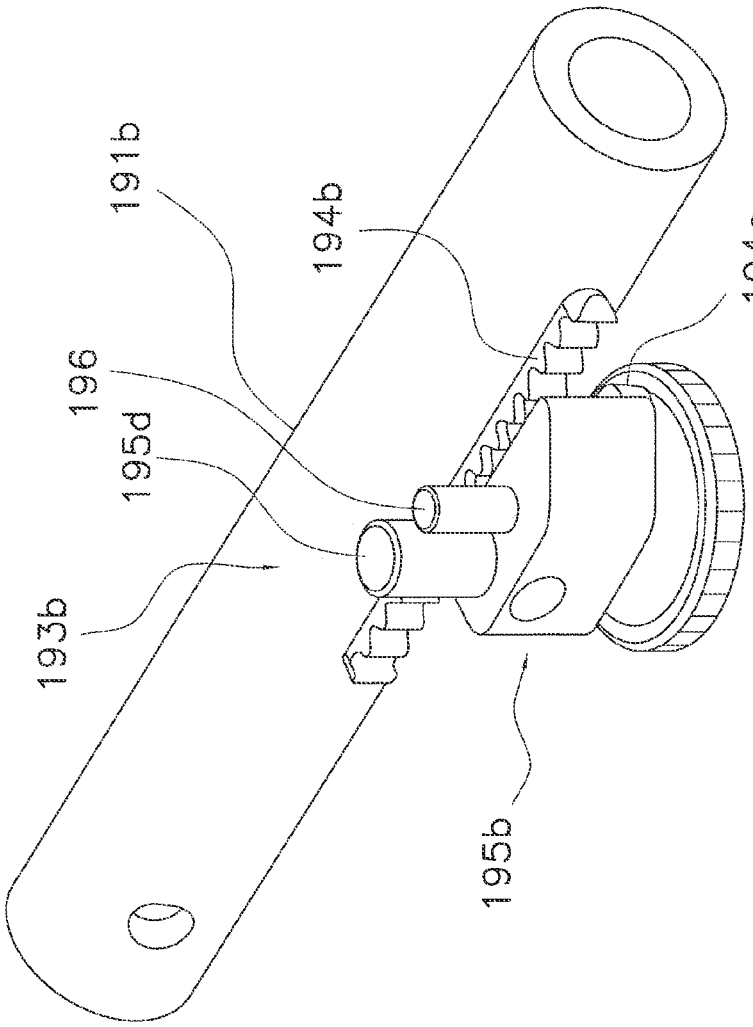

FIG. 16

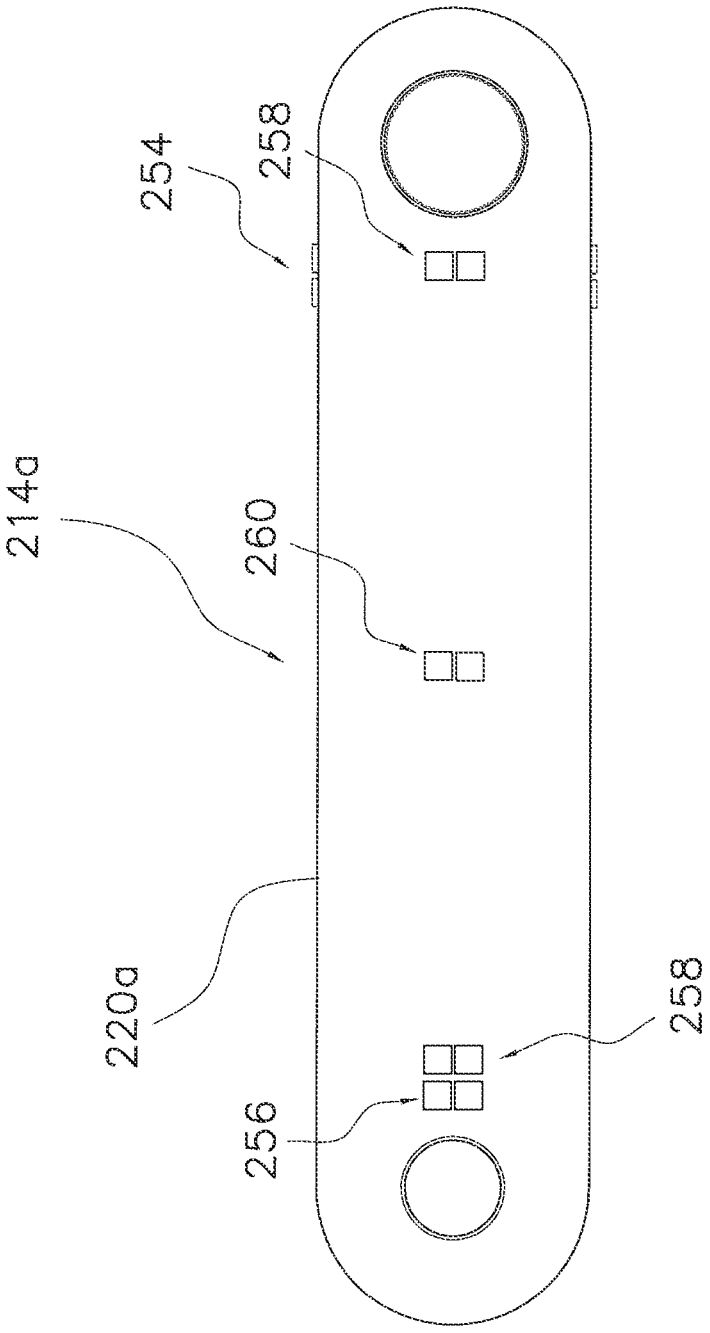

FIG. 17

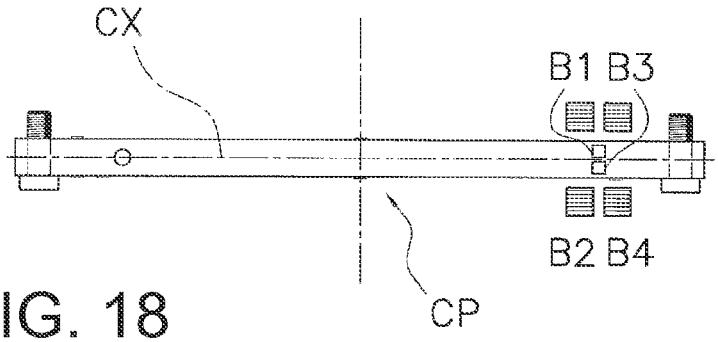

FIG. 18

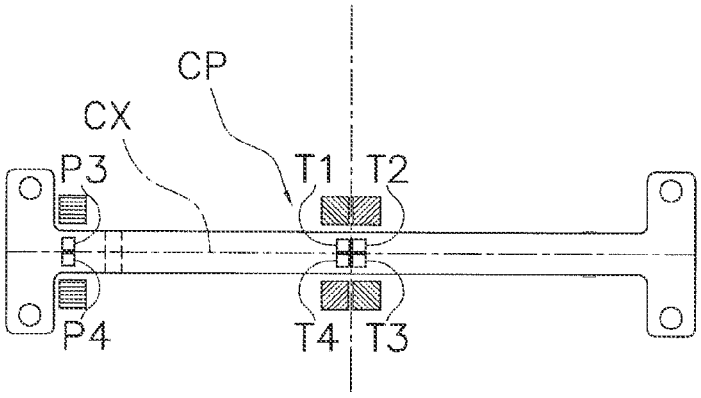

FIG. 19

$$DL = \frac{\Sigma(LF\theta)}{\Sigma\sqrt{LF\theta^2 + LFr^2 + LFz^2}} = \frac{\text{SUM OF LF}\theta\text{ DURING ONE ROTATION OF SECOND CRANK ARM}}{\text{SUM OF LF DURING ONE ROTATION OF SECOND CRANK ARM}}$$

$$DR = \frac{\Sigma(RF\theta)}{\Sigma\sqrt{RF\theta^2 + RFr^2 + RFz^2}} = \frac{\text{SUM OF RF}\theta\text{ DURING ONE ROTATION OF FIRST CRANK ARM}}{\text{SUM OF RF DURING ONE ROTATION OF FIRST CRANK ARM}}$$

$$D = \frac{\Sigma(LF\theta + RF\theta)}{\Sigma\left(\sqrt{LF\theta^2 + LFr^2 + LFz^2} + \sqrt{RF\theta^2 + RFr^2 + RFz^2}\right)} = \frac{\text{(SUM OF F}\theta\text{ DURING ONE CRANK ROTATION)}}{\text{(SUM OF F DURING ONE CRANK ROTATION)}}$$

$LF\theta$: Fθ OF SECOND CRANK ARM

LFr : Fr OF SECOND CRANK ARM

LFz : Fz OF SECOND CRANK ARM

LF : COMPOSITE VECTOR FOR SECOND CRANK ARM

F : SUM OF LF AND RF

$RF\theta$: Fθ OF FIRST CRANK ARM

RFr : Fr OF FIRST CRANK ARM

RFz : Fz OF FIRST CRANK ARM

RF : COMPOSITE VECTOR FOR FIRST CRANK ARM

FIG. 20

PEDALING FORCE MEASUREMENT DEVICE

GROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to Japanese Patent Application No. 2012-188126, filed on Aug. 28, 2012. The entire disclosure of Japanese Patent Application No. 2012-188126 is hereby incorporated herein by reference.

BACKGROUND

1. Field of the Invention

This invention generally relates to a pedaling force measurement device for measuring a plurality of parameters for pedaling force acting on a crank arm having a pedal attachable on one end and a crankshaft attachable on the other end, the pedaling force being due to the pedal being pushed.

2. Background Information

Pedaling force measurement devices are known in the prior art for measuring pedaling force acting on a bicycle crank arm in terms of a plurality of parameters due to a pedal being pushed (for example, see PCT International Publication No. WO/2011/030215). In a conventional pedaling force measurement device, parameters in the for of a vertical force component of the bending moment, a longitudinal force component of the bending moment, and the position of the pedal in the pedal axial direction acting on the crank arm are measured using a strain gauge. The measured parameters are displayed on a display device.

SUMMARY

It is difficult to measure a single parameter, such as a bending moment force component, with high precision using a conventional pedaling force measurement device due to the influence of the other parameters.

A pedaling force measurement device according to a first aspect of the present invention measures a plurality of parameters of pedaling force acting on a crank arm. The pedaling force measurement device comprising a strain-flexing part, a parameter detection part and an interference suppression part. The strain-flexing part is configured to receive a strain acting on the crank arm from pedaling. The parameter detection part is disposed on the strain-flexing part to detect the parameters from the strain acting on the strain-flexing part. The interference suppression part is configured to suppress interference from one parameter detected by the parameter detection part from other ones of the parameters.

When a crankshaft is mounted to another end of the crank arm of the pedaling force measurement device, a pedal is mounted to one end of the crank arm, and the pedal is pushed, a plurality of pedaling force parameters are detected and measured. At this time, errors in the detected output for one parameter may arise due to one parameter being subjected to interference from the other parameters. Such interference is suppressed by the interference suppression part. It is thus possible to precisely measure pedaling force parameters.

A pedaling force measurement device according to a second aspect of the present invention is the pedaling force measurement device according to the first aspect, wherein the parameter detection part comprises a second strain sensor and a third strain sensor. The second strain sensor is configured to detect a second force component, corresponding to a crank arm longitudinal force component of a bending moment due to a load acting upon the crank arm from pedaling, as one of the parameters. The third strain sensor is configured to detect a third force component, corresponding to a pedal axial direction force component of the bending moment due to the load acting upon the crank arm from pedaling, as one of the parameters. In this case, the second force component, which constitutes a force component in the longitudinal direction, i.e., the direction of tension, can be detected by the second strain sensor, and the third force component, which constitutes the pedal axial direction force component, by the third strain sensor.

A pedaling force measurement device according to a third aspect of the present invention is the pedaling force measurement device according to the second aspect, wherein the parameter detection part comprises a first strain sensor and a fourth strain sensor. The first strain sensor is configured to detect a first force component, corresponding to a rotational direction force component of the bending moment due to the load acting upon the crank arm from pedaling, as one of the parameters. The fourth strain sensor is configured to detect a fourth force component, corresponding to a shear force the load acting upon the crank arm, as one of the parameters to determine an axial direction load position from pedaling. In this case, the first force component, which constitutes a rotational direction force component of the crank arm, and the load position of the pedal being pushed by the user can be detected in addition to the second force component and the third force component. It is thus possible to detect the direction of the force applied during pedaling from a variety of angles.

A pedaling force measurement device according to a fourth aspect of the present invention is the pedaling force measurement device according to the third aspect, wherein each of the first through fourth strain sensors comprises at least two strain gauge elements forming a Wheatstone bridge circuit. It is thus possible to detect the first through the third force components and the load position using two strain gauge elements.

A pedaling force measurement device according to a fifth aspect of the present invention is the pedaling force measurement device according to the fourth aspect, wherein each of the first through fourth strain sensors comprises four strain gauge elements forming a Wheatstone bridge circuit. Temperature compensation of the strain gauge elements is thereby enabled, allowing for the suppression of variations in detection accuracy arising from temperature changes.

A pedaling force measurement device according to a sixth aspect of the present invention is the pedaling force measurement device according to the fifth aspect, wherein the strain-flexing part has a first surface, a second surface, a third surface and a fourth surface extending in a longitudinal direction of the crank arm. The first surface and the fourth surface are substantially perpendicular to the shaft of the pedal. The second surface and the third surface are substantially parallel to a shaft of the pedal. In this case, the provision of a strain gauge element on a surface substantially parallel with the shaft of the pedal allows the rotational direction first force component of the bending moment to be detected, and the provision of a strain gauge element on a surface substantially perpendicular to the pedal shaft allows the shear force moment, the pedal axial direction third force component of the bending moment, and the crank arm longitudinal direction second force component of the bending moment to be detected.

A pedaling force measurement device according to a seventh aspect of the present invention is the pedaling force measurement device according to the sixth aspect, wherein the strain-flexing part comprises a quadrangular prism. In this

case, strain gauge elements can easily be applied to the surfaces of the quadrangular prism, allowing for improved productivity.

A pedaling force measurement device according to an eighth aspect of the present invention is the pedaling force measurement device according to the sixth or seventh aspect, wherein the four strain gauge elements forming the third strain sensor are disposed on one of the first and fourth surfaces of the strain-flexing part. The Wheatstone bridge circuit of the third strain sensor has a first pair of oppositely disposed strain gauge elements of the four strain gauge elements of the third strain sensor and a second pair of oppositely disposed strain gauge elements of the four strain gauge elements of the third strain sensor. The first pair of oppositely disposed strain gauge elements is spaced from the second pair of oppositely disposed strain gauge elements in the longitudinal direction of the crank arm. The first and second pairs of oppositely disposed strain gauge elements are symmetrically disposed with respect to a longitudinal neutral axis of the strain-flexing part.

In this case, the third force component is measured on the basis of the difference in bending moment between the position of the strain gauge elements disposed apart from each other in the longitudinal direction, and the third force component can be independently measured without interference from the first force component, second force component, or shear force.

A pedaling three measurement device according to a ninth aspect of the present invention is the pedaling force measurement device according to the sixth or seventh aspect, wherein the four strain gauge elements forming the third strain sensor are disposed on one of the first and fourth surfaces of the strain-flexing part. The Wheatstone bridge circuit of the third strain sensor has first, second, third and fourth strain gauge elements forming the four strain gauge elements of the third strain sensor. The first and third strain gauge elements are oppositely disposed from each other in the Wheatstone bridge circuit of the third strain sensor. The second and fourth strain gauge elements are disposed between the first and third strain gauge elements. The first and third strain gauge elements is symmetrically disposed with respect to a longitudinal neutral axis of the strain-flexing part and disposed at one end of the strain-flexing part. The second and fourth strain gauge elements is symmetrically disposed with respect to the longitudinal neutral axis of the strain-flexing part and disposed at the other end of the strain-flexing part.

In this case, the third force component can be measured on the basis of the difference in bending moment between the positions of the strain gauge elements disposed apart from each other in the longitudinal direction. The third force component can be independently measured without interference from the first force component, second three component, or shear force. Because the strain gauge elements of the third strain sensor are disposed on both ends of the strain-flexing part, the output of the sensor can be increased.

A pedaling force measurement device according to a tenth aspect of the present invention is the pedaling force measurement device according to one of the sixth through the ninth aspects, wherein the four strain gauge elements forming the first strain sensor are disposed on one end of the strain-flexing part. The Wheatstone bridge circuit of the first strain sensor has first, second, third and fourth strain gauge elements forming the four strain gauge elements of the first strain sensor. The first and third strain gauge elements are oppositely disposed from each other in the Wheatstone bridge circuit of the first strain sensor. The second and fourth strain gauge elements are disposed between the first and third strain gauge elements. The first and third strain gauge elements are disposed on one of the second and third surfaces, while the second and fourth strain gauge elements being disposed on the other of the second and third surfaces. The first and third strain gauge elements are symmetrically disposed with respect to a longitudinal neutral axis of the strain-flexing part. The second and fourth strain gauge elements are symmetrically disposed with respect to the longitudinal neutral axis of the strain-flexing part.

In this case, the first strain sensor is disposed on the other end of the strain-flexing part, where the first force component constituting the rotational direction force component of the bending moment of the crank arm is larger, allowing for the output of the strain gauge element to be increased.

A pedaling force measurement device according to an eleventh aspect of the present invention is the pedaling force measurement device according to one of the sixth through the ninth aspects, wherein the four strain gauge elements forming the first strain sensor are disposed on one end of the strain-flexing part. The Wheatstone bridge circuit of the first strain sensor has first, second, third and fourth strain gauge elements forming the four strain gauge elements of the first strain sensor. The first and third strain gauge elements are oppositely disposed from each other in the Wheatstone bridge circuit of the first strain sensor. The second and fourth strain gauge elements are disposed between the first and third strain gauge elements. The first and third strain gauge elements are disposed on one of the second and third surfaces, while the second and fourth strain gauge elements being disposed on the other of the second and third surfaces. The first and third strain gauge elements are aligned in the longitudinal direction of the strain-flexing part. The second and fourth strain gauge elements are aligned in the longitudinal direction of the strain-flexing part.

In this case, the first strain sensor is disposed on the other end of the strain-flexing part, where the first force component constituting the rotational direction force component of the bending moment of the crank arm is larger, allowing for the output of the strain gauge element to be increased.

A pedaling force measurement device according to a twelfth aspect of the present invention is the pedaling force measurement device according to one of the sixth through the eleventh aspects, wherein the four strain gauge elements forming the second strain sensor are disposed on one end of the strain-flexing part. The Wheatstone bridge circuit of the first strain sensor has first, second, third and fourth strain gauge elements forming the four strain gauge elements of the second strain sensor. The first and third strain gauge elements are oppositely disposed from each other in the Wheatstone bridge circuit of the second strain sensor. The second and fourth strain gauge elements are disposed between the first and third strain gauge elements. The first and third strain gauge elements are disposed on one of the first and fourth surfaces, while the second and fourth strain gauge elements being disposed on the other of the first and fourth surfaces. The first and third strain gauge elements are symmetrically disposed with respect to a longitudinal neutral axis of the strain-flexing part. The second and fourth strain gauge elements are symmetrically disposed with respect to the longitudinal neutral axis of the strain-flexing part.

In this case, the output of the second strain sensor, which detects the second force component constituting the longitudinal force component of the crank arm bending moment, is less subject to interference from the pedal axial direction force component of the bending moment of the load acting on the crank arm.

A pedaling force measurement device according to a thirteenth aspect of the present invention is the pedaling force measurement device according to one of the sixth through the twelfth aspects, wherein the four strain gauge elements forming the fourth strain sensor are disposed at a center area of the strain-flexing part with respect to the longitudinal direction of the strain-flexing part. The Wheatstone bridge circuit of the first strain sensor has first, second, third and fourth strain gauge elements forming the four strain gauge elements of the fourth strain sensor. The first and third strain gauge elements are oppositely disposed from each other in the Wheatstone bridge circuit of the fourth strain sensor, the second and fourth strain gauge elements being disposed between the first and third strain gauge elements. The first and second strain gauge elements are disposed on one of the first and fourth surfaces, while the third and fourth strain gauge elements being disposed on the other of the first and fourth surfaces. The first and second strain gauge elements are symmetrically disposed with respect to a longitudinal neutral axis of the strain-flexing part. The third and fourth strain gauge elements are symmetrically disposed with respect to the longitudinal neutral axis of the strain-flexing part.

In this case, interference from the first force component, the second force component, and the third force component is reduced, and the shear force of the shear moment of the load acting on the crank arm can be measured.

A pedaling force measurement device according to a fourteenth aspect of the present invention is the pedaling force measurement device according to one of the sixth through the twelfth aspects, wherein the four strain gauge elements forming the fourth strain sensor are disposed at a center of the strain-flexing part with respect to the longitudinal direction of the strain-flexing part. The Wheatstone bridge circuit of the first strain sensor has first, second, third and fourth strain gauge elements forming the four strain gauge elements of the fourth strain sensor. The first and third strain gauge elements are oppositely disposed from each other in the Wheatstone bridge circuit of the fourth strain sensor. The second and fourth strain gauge elements are disposed between the first and third strain gauge elements. The first, second, third and fourth strain gauge elements are disposed on one of the first and fourth surfaces. The first and second strain gauge elements are symmetrically disposed with respect to a longitudinal neutral axis of the strain-flexing part. The third and fourth strain gauge elements are symmetrically disposed with respect to the longitudinal neutral axis of the strain-flexing part.

In this case, interference from the first force component, the second force component, and the third force component is reduced, and the shear force of the shear moment of the load acting on the crank arm can be measured.

A pedaling force measurement device according to a fifteenth aspect of the present invention is the pedaling force measurement device according to one of the first through the fourteenth aspects, wherein the interference suppression part is formed at a location that is displaced from a central position in a longitudinal direction of the crank arm towards a pedal mounting end of the strain-flexing part, and an area of the location of the interference suppression part has a cross section orthogonal to the longitudinal direction that is different than elsewhere along the crank arm. In this case, simply varying cross-sectional area allows for the easy suppression of interference.

A pedaling force measurement device according to a sixteenth aspect of the present invention is the strain-flexing part according to the fifteenth aspect, wherein the interference suppression part includes a through-hole formed in the strain-flexing part. In this case, the interference suppression part is more easily formed.

A pedaling force measurement device according to a seventeenth aspect of the present invention is the pedaling force measurement device according to one of the second through the sixteenth aspects, wherein the interference suppression part is programmed to perform a computational process to suppress interference from the third force component outputted from the third strain sensor while detecting the second force component based on outputs of the second strain sensor. In this case, the computational process enables the interfering third force component contained within the second force component to be suppressed, allowing for accurate measurement of the second force component.

A pedaling force measurement device according to an eighteenth aspect of the present invention is the pedaling force measurement device according to one of the third through the seventeenth aspects, wherein the interference suppression part is programmed to perform a computational process to suppress interference from the third force component based on outputs of the first, second, third and fourth strain sensors. In this case, the computational process is performed on the basis of the output of the four strain sensors, allowing for even more precise suppression of interference.

A pedaling force measurement device according to a nineteenth aspect of the present invention is the pedaling force measurement device according to one of the first through the eighteenth aspects, wherein the strain-flexing part is provided separately from the crank arm. In this case, the strain-flexing part is provided separately from the crank arm, allowing for the provision of a strain-flexing part even on a crank arm having a complex shape. In addition, the same strain-flexing part can be used with crank arms of a variety of shapes, enabling standardization of the strain-flexing part. Moreover, the crank arm and the strain-flexing part can be manufactured separately, allowing for improved productivity and ease of maintenance.

A pedaling force measurement device according to a twentieth aspect of the present invention is the pedaling force measurement device according to one of the first through the eighteenth aspects, further provided with a crank arm.

A pedaling force measurement device according to a twenty-first aspect of the present invention is the pedaling force measurement device according to the twentieth aspect, wherein the crank arm comprises a pedal attachment part for attaching the pedal, a crankshaft attachment part for attaching the crankshaft and a crank length adjustment mechanism adjustably coupling the pedal attachment part to the crankshaft attachment part for altering relative positions of the pedal attachment part and the crankshaft attachment part in a longitudinal direction of the crank arm. In this case, the plurality of pedaling force parameters can be measured at altered relative positions for the pedal attachment part and the crank shaft attachment part, allowing a crank length optimal for a user to be obtained.

A pedaling force measurement device according to a twenty-second aspect of the present invention is the pedaling force measurement device according to the twenty-first aspect, wherein the strain-flexing part is attached to the pedal attachment part. In this case, there is no change in the relative positions of the pedal attachment position and the strain-flexing part, allowing for effects upon the output of the parameter detection part arising from changes in the relative positions of the pedal attachment part and the crank shaft attachment part to be suppressed.

A pedaling force measurement device according to a twenty-third aspect of the present invention is the pedaling force measurement device according to one of the first through the eighteenth aspects, wherein the strain-flexing part is integrally formed with the crank arm. In this case, there is no need to provide a separate strain-flexing part, simplifying the configuration of the pedaling force measurement device.

According to the present invention, it is possible to suppress interference in one parameter out of a plurality of pedaling force parameters acting upon a crank arm via a pedal being pushed from other parameters, and to suppress errors in the detected parameter. It is thus possible to precisely measure pedaling force parameters.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the attached drawings which form a part of this original disclosure:

FIG. **1** is an exploded perspective view of a pedaling force measurement device according to a first embodiment of the present invention;

FIG. **2** is a front via of an arm body of a crank arm;

FIG. **3** is a plan view of a strain-flexing part;

FIG. **4** is a view of the rear surface of a strain-flexing part as seen through the front surface;

FIG. **5** is a front view of a strain-flexing part;

FIG. **6** is a cross-sectional view along line VI-VI in FIG. **5**;

FIG. **7** is a circuit diagram showing the disposition of strain gauges in a Wheatstone bridge of a first strain sensor;

FIG. **8** is a circuit diagram showing the disposition of strain gauges in a Wheatstone bridge of a second strain sensor;

FIG. **9** is a circuit diagram showing the disposition of strain gauges in a Wheatstone bridge of a third strain sensor;

FIG. **10** is a circuit diagram showing the disposition of strain gauges in a Wheatstone bridge of a fourth strain sensor;

FIG. **11** is a block diagram of the configuration of control system for a pedaling force measurement device;

FIG. **12** is an illustration of an example of a display of pedaling force parameters measured by a pedaling force measurement device;

FIG. **13** is a perspective view including a pedaling force measurement device according to a second embodiment;

FIG. **14** is a plan view of a crank arm;

FIG. **15** is a cross-sectional view showing the configuration of a crank length adjustment mechanism for a crank arm;

FIG. **16** is a perspective view showing the configuration of a crank length adjustment mechanism;

FIG. **17** is an illustration corresponding to FIG. **2** for another embodiment;

FIG. **18** is an illustration corresponding to FIG. **3** for a modified example of the disposition of the first strain sensor;

FIG. **19** is an illustration corresponding to FIG. **4** for a modified example of the disposition of the fourth strain sensor; and

FIG. **20** shows formulas for the items shown on the display screen shown in FIG. **13**.

DETAILED DESCRIPTION OF EMBODIMENTS

Selected embodiments will now be explained with reference to the drawings. It will be apparent to those skilled in the bicycle field from this disclosure that the following descriptions of the embodiments are provided for illustration only and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

In FIG. **1**, a crank assembly **10** according to a first embodiment of the present invention is provided with a crank shaft **12**, a first pedaling force measurement device **14***a*, a second pedaling force measurement device **14***b*, and a sprocket **15**. The crank shaft **12** has a first end **12***a* and a second end **12***b*. The first pedaling force measurement device **14***a* is coupled to the first end **12***a* of the crank shaft **12** so as to be capable of rotating integrally with the crank shaft **12**. The second pedaling force measurement device **14***b* is coupled to the second end **12***b* of the crank shaft **12** so as to be capable of rotating integrally with the crank shaft **12**. Here, the first end **12***a* of the crank shaft **12** is disposed to the right side of a bicycle as seen from behind when the crank assembly **10** is mounted on the bicycle, and the second end **12***b* is disposed to the left side. In the present embodiment, the crank shaft **12** is formed in a hollow cylindrical shape.

The first pedaling force measurement device **14***a* has a first crank arm **20***a* capable of being coupled to the first end **12***a* of the crank shaft **12** so as to be capable of rotating integrally with the crank shaft **12**. A first pedal **16***a* can be attached to one end **31***a***1** in the longitudinal direction of the first crank arm **20***a*, and the first end **12***a* of the crank shaft **12** can be attached to another end **31***a***2** in the longitudinal direction, The first pedaling force measurement device **14***a* is a device for measuring a plurality of pedaling force parameters acting on the first crank arm **20***a* due to the first pedal **16***a* being pushed. The first pedaling force measurement device **14***a* is provided with a first crank arm **20***a*, a strain-flexing part **22**, a parameter detection part **24**, and a through-hole **26** serving as an interference suppression part **26**. The strain-flexing part **22** is detachably provided on the first crank arm **20***a*, and strain acting on the first crank arm **20***a* is conveyed thereto. The parameter detection part **24** is disposed on the strain-flexing part **22**, and detects a plurality of parameters on the basis of the strain being conveyed to the strain-flexing part **22**. The interference suppression part **26** suppresses interference in one parameter detected by the parameter detection part **24** from the other parameters.

The sprocket **15** is anchored to the first crank arm **20***a* via a sprocket attachment part **75**. The sprocket attachment part **75** is anchored to the first crank arm **20***a* by an anchoring member not shown in the drawings, such as a bolt. The sprocket attachment part **75** has an insertion hole into which the crank shaft **12** is inserted, and a plurality of radially extending arms. Anchoring parts, such as bolts, for anchoring the inner periphery of the sprocket **15** are provided on the arms, and the sprocket **15** is detachably anchored to the arms. The sprocket attachment part **75** may be press-fitted to the crank shaft **12**, or may be formed integrally with the first crank arm **20***a*.

The second pedaling force measurement device **14***b* has a configuration similar to that of the first pedaling force measurement device **14***a*, and is a device for measuring a plurality of pedaling force parameters acting on a second crank arm **20***b* due to a second pedal **16***b* being pressed. The second pedaling force measurement device **14***b* has the second crank arm **20***b*, as well as a strain-flexing part **22**, a parameter detection part **24**, and an interference suppression part **26** configured similarly to those of the first pedaling force measurement device **14***a*, none of the latter three being shown in the drawings. In the following description, therefore, description of those features of the second pedaling force measurement device **14***b* similar to the first pedaling force measurement device **14***a* will be omitted, and features similar to those of the first pedaling force measurement device **14***a* will be labeled with similar reference numbers in FIG. **1**, the features being distinguished by suffixed letters "a" and "b".

The first crank arm **20***a* and the second crank arm **20***b* are both rod-shaped members extending in the longitudinal

direction. The two ends of the first crank arm **20***a* and the second crank arm **20***b* have rounded hemispherical shapes, but there is no particular limitation upon the shapes of the ends. The first crank arm **20***a* has a first arm body **30***a* and a first arm cover **32***a* covering the first arm body **30***a*. The second crank arm **20***b* has a second arm body **30***b* and a second arm cover **32***b* covering the second arm body **30***b*.

As shown in FIG. **2**, the first arm body **30***a* has a first pedal attachment part **34***a* on the one end **31***a***1** in the longitudinal direction to which the first pedal **16***a* can be attached. The first arm body **30***a* has a first crank shaft attachment part **36***a* capable of being anchored first end **12***a* of the crank shaft **12** via suitable anchoring means, such as press fitting or bolts, on the other end **31***a***2** in the longitudinal direction. In the present embodiment, the first end **12***a* of the crank shaft **12** is anchored to the first crank shaft attachment part **36***a* by press fitting. A pedal shaft **17***a* of the first pedal **16***a* can be detachably anchored to the first pedal attachment part **34***a*. The first pedal attachment part **34***a* has, for example, a first screw hole **35***a* into which the pedal shaft **17***a* screws. The first crank shaft attachment part **36***a* has a first attachment hole **37***a*. Serrations are formed in the inner periphery facing the first attachment hole **37***a* of the first crank shaft attachment part **36***a*, and the first end **12***a* of the crank shaft **12** is press-fitted and anchored to the first attachment hole **37***a*. Here, the first attachment hole **37***a* is a through-hole, but the first attachment hole **37***a* can also be formed as an indentation.

The first arm body **30***a* also has a first housing part **38***a* in which a strain-flexing part **22***a* is housed between the first pedal attachment part **34***a* and the first crank shaft attachment part **36***a*. The first housing part **38***a* is formed as an indentation. In the present embodiment, the first housing part **38***a* opens away from a bicycle in the direction in which the crank shaft extends when the crank assembly **10** is attached to the bicycle. The first housing part **38***a* has first attachment parts **39***a* along both sides in the longitudinal direction of the first crank arm **20***a* for anchoring the strain-flexing part **22***a* to the first crank arm **20***a*. Two anchoring holes **40***a* into which anchoring bolts **42** for anchoring the strain-flexing part **22***a* are formed in each of the first attachment parts **39***a*. The anchoring holes **40***a* in the first attachment parts **39***a* are symmetrically disposed with respect to a plane containing the pedal shaft **17***a* and the crank shaft **12**. In the present embodiment, the anchoring holes **40***a* are screw holes. An annular first difference in level **41***a* for mounting the first arm cover **32***a* is formed on the outer periphery of the first arm body **30***a*. The first difference in level **41***a* is formed as an indentation in the outside surface having a depth identical to the thickness of a first rim **44***a* of the first arm cover **32***a* to be described hereafter.

As shown in FIG. **1**, the first arm cover **32**.*a* has a first cover **43***a* for covering the first housing part **38***a* and a first rim **44***a* annularly projecting from the circumferential edge of the first cover **43***a* towards the first arm body **30***a*. The inner periphery of the first rim **44***a* mates with the first difference in level **41***a* in the first arm body **30***a*. The first cover **43***a* is provided from the one end **31***a***1** of the first crank arm **20***a* in the longitudinal direction to the other end **31***a***2** so as to entirely cover one side of the first arm body **30***a*. To this end, the first cover **43***a* has a first through-hole **47***a*, communicating with the first screw hole **35***a*, through which the pedal shaft **17***a* of the first pedal **16***a* can pass, and a second through-hole **46***a* communicating with the first attachment hole **37***a*. The second through-hole **46***a* is formed at a diameter similar to that of the first attachment hole **37***a*. Here, a second through-hole **46***a* is formed, but it is also acceptable not to form a second through-hole **46***a*. The first arm cover **32***a* is anchored to the first arm body **30***a* by a plurality (for example, 4) of screw members **45***a*. The anchoring method is not limited to screws; an anchoring method such as bonding or elastic engagement is also acceptable.

As shown in FIG. **1**, the second crank arm **20***b* has a second arm body **30***b* and a second arm cover **32***b* covering the second arm body **30***b*. The second arm body **30***b* is configured differently from the first arm body **30***a* and a second crank shaft attachment part **36***b*. The second crank shaft attachment part **36***b* has a serrated second attachment hole **37***b* in which a slit **37***c* is formed. The slit **37***c* extends to the outer surface of the second arm body **30***b*. The width of the slit **37***c* is reduced by a tightening bolt **46***b* inserted from a direction intersecting the slit **37***c*. The second crank arm **20***b* is thereby anchored to the second end **12***b* of the crank shaft **12**. Other features are identical to those of first crank arm **20***a*, and description thereof will therefore be omitted.

As shown in FIGS. **2**, **3**, **4**, and **5**, the strain-flexing part **22** has a strain-flexing part body **50** extending in the longitudinal direction of the first crank arm **20***a*, and anchor portions **51** at both ends of the strain-flexing part body **50** extending in a direction moving away from the strain-flexing part body **50** in a direction orthogonal to the strain-flexing part body **50**. The strain-flexing part **22** has a flattened letter H shape. The strain-flexing part body **50** is formed as a quadrangular prism.

FIG. **6** shows a cross section of the strain-flexing part body **50**. As shown in FIG. **6**, the strain-flexing part body **50** has a first surface **52***a*, a second surface **52***b*, a third surface **52***c*, and a fourth surface **52***d* extending in the longitudinal direction of the first crank arm **20***a*. In the present embodiment, the first surface **52***a*, second surface **52***b*, third surface **52***c*, and fourth surface **52***d* of the strain-flexing part body **50** are all of the same size. The first surface **52***a* and the fourth surface **52***d* facing the first surface **52***a* are substantially perpendicular to the pedal shaft **17***a* of the first pedal **16***a* shown in FIG. **1**. The second surface **52***b* and the third surface **5** facing the second surface **52***b* are substantially parallel with the pedal shaft **17***a* of the first pedal **16***a* shown in FIG. **1**. The bend and shear of the strain-flexing part body **50** are detected by the parameter detection part **24**, allowing the plurality of parameters to be measured.

Two anchoring holes **51***a* are formed in each of the anchor portions **51** separated from each other in a direction orthogonal to the lengthwise direction. The anchoring holes **51***a* are symmetrically provided on either side of the strain-flexing part body **50**. The anchoring holes **51***a* are formed by through-holes, and extend in a direction substantially parallel to the shaft **17***a* of the pedal **16***a*. The anchoring bolts **42** for anchoring the strain-flexing part **22** in the first housing part **38***a* are screwed the anchoring holes **40***a* through the anchoring holes **51***a*.

The strain-flexing part body **50** is provided so that the first arm body **30***a* and the first arm cover **32***a* do not touch when the strain-flexing part **22** is anchored to the crank arm **20***a*.

As shown in FIGS. **2**, **3**, and **4**, the parameter detection part **24** has a first strain sensor **54** for detecting a first force component Fθ, a second strain sensor **56** for detecting a second force component Fr, a third strain sensor for detecting a third force component Fz, and a fourth strain sensor **60** for detecting the shear force of the load acting on the first crank arm **20***a* in order to find a load position L.

As shown in FIG. **1**, the first force component Fθ is a rotational direction force component of the bending moment of the load acting on the first crank arm **20***a*. The second force component Fr is a force component in the longitudinal direction of the first crank arm **20***a* for the bending moment of the load acting on the first crank arm **20***a*. The third force com-

ponent Fz is a force component in the axial direction of the first pedal **16***a* for the bending moment of the load acting on the first crank arm **20***a*. The load position L is the position in the axial direction of the first pedal **16***a* where the user pushes the first pedal **16***a*, and the length in the axial direction from the outer surface of the first crank arm **20***a* to the position on the first pedal **16***a* acted on by the load.

The first strain sensor **54** has four strain gauge elements B**1**, B**2**, B**3**, and **94** forming a Wheatstone bridge circuit. The second strain sensor **56** has four strain gauge elements P**1**, P**2**, P**3**, and P**4** forming a Wheatstone bridge circuit. The third strain sensor **58** has four strain gauge elements A**1**, A**2**, A**3**, and A**4** forming a Wheatstone bridge circuit. The fourth strain sensor **60** has four strain gauge elements T**1**, T**2**, T**3**, and T**4** forming a Wheatstone bridge circuit.

The four strain gauge elements B**1**, B**2**, B**3**, and B**4** constituting the first strain sensor **54** are disposed on the other end (in FIG. **3**, the right end) of the strain-flexing part **22**. The strain gauge elements B**1**, B**2**, B**3**, and B**4** are disposed on the other end of the strain-flexing part body **50** at positions not contacting the crank arm **20***a*. As shown in FIG. **7**, the strain gauge element B**1** disposed on a first side **62***a* of the four sides of the Wheatstone bridge circuit **62** in the first strain sensor **54** and the strain gauge element B**3** disposed on a second side **62***b* facing the first side **62***a* are disposed on the second surface **52***b*. As shown in FIGS. **3** and **6**, the strain gauge element B**2** disposed on a third side **62***c* between the first side **62***a* and the second side **62***b* of the Wheatstone bridge circuit **62** and the strain gauge element B**4** disposed on a fourth side **62***d* between the first side **62***a* and the second side **62***b* are disposed on the third surface **52***c*.

The two strain gauge elements B**1** and B**3** disposed on the second surface **52***b* are aligned in the longitudinal direction over a longitudinal neutral axis CX of the strain-flexing part **22**. The two strain gauge elements B**2** and B**4** disposed on the third surface **52***c* are aligned in the longitudinal direction over the longitudinal neutral axis CX of the strain-flexing part **22**. In other words, in the first strain sensor **54**, two strain gauge elements disposed on the same surface are aligned in the longitudinal direction over the longitudinal neutral axis CX of the strain-flexing part **22**. The directions in which the strain gauge elements B**1**, B**2**, B**3**, and B**4** detect strain are disposed along the longitudinal direction of the crank arm **20***a*.

The strain gauge element B**1** and the strain gauge element B**2** are disposed at overlapping positions sandwiching the strain-flexing part body **50**. The strain gauge elements B**3** and the strain gauge element B**4** are also disposed at overlapping positions sandwiching the strain-flexing part body **50**.

It is also acceptable thr the strain gauge element B**1** and the strain gauge element B**3** disposed on the second surface **52***b* to be symmetrically disposed with respect to the longitudinal neutral axis CX of the strain-flexing part **22**, and the strain gauge element B**2** and strain gauge element B**4** disposed on the third surface **52***c* to be symmetrically disposed with respect to the longitudinal neutral axis CX of the strain-flexing part **22**, as shown in FIG. **18**. In other words, in the first strain sensor **54**, two strain gauge elements disposed on the same surface may be symmetrically disposed with respect to the longitudinal neutral axis CX of the strain-flexing part **22**. The strain gauge element B**1** and the strain gauge element B**2** are also disposed at overlapping positions sandwiching the strain-flexing part body **50**. The strain gauge elements B**3** and the strain gauge element B**4** are also disposed at overlapping positions sandwiching the strain-flexing part body **50**.

The four strain gauge elements P**1**, P**2**, P**3**, and P**4** constituting the second strain sensor **56** are disposed on the one end (in FIG. **4**, the left end) of the strain-flexing part **22**. The strain gauge elements P**1**, P**2**, P**3**, and P**4** are disposed on the one end of the strain-flexing part body **50** at positions not contacting the crank arm **20***a*. As shown in FIG. **8**, the strain gauge element P**2** disposed on a first side **64***a* of the four sides of the Wheatstone bridge circuit **64** in the second strain sensor **56** and the strain gauge element P**4** disposed on a second side **64***b* facing the first side **64***a* are disposed on the fourth surface **52***d*. The strain gauge element P**1** disposed on a third side **64***c* between the first side **64***a* and the second side **64***b* of the Wheatstone bridge circuit **64** and the strain gauge element P**3** disposed on a fourth side **64***d* between the first side **64***a* and the second side **64***b* are disposed on the first surface **52***a*, as shown in FIGS. **4** and **5**. The two strain gauge elements P**1** and P**3** disposed on the first surface **52***a* are symmetrically disposed with respect to the longitudinal neutral axis CX of the strain-flexing part **22**. The two strain gauge elements P**2** and P**4** disposed on the fourth surface **52***d* are symmetrically disposed with respect to the longitudinal neutral axis CX of the strain-flexing part **22**. In other words, in the second strain sensor **56**, two strain gauge elements disposed on the same surface are symmetrically disposed with respect to the longitudinal neutral axis CX of the strain-flexing part **22**. The directions in which the strain gauge elements P**1**, P**2**, P**3**, and P**4** detect strain are disposed along the longitudinal direction of the crank arm **20***a*. The strain gauge element P**1** and the strain gauge element P**2** are disposed at overlapping positions sandwiching the strain-flexing part body **50**. The strain gauge element P**3** and the strain gauge element P**4** are also disposed at overlapping positions sandwiching the strain-flexing part body **50**.

The four strain gauge elements A**1**, A**2**, A**3**, and A**4** constituting the third strain sensor **58** are disposed on the first surface **52***a*. It is also acceptable for the third strain sensor **58** to be disposed on the fourth surface **52***d*. As shown in FIG. **9**, the strain gauge element A**2** disposed on a first side **66***a* of the four sides of the Wheatstone bridge circuit **66** constituting the third strain sensor **58** and the strain gauge element A**4** disposed on a second side **66***b* facing the first side **66***a* are disposed on the other end (in FIG. **5**, the right end) of the strain-flexing part **22**, as shown in FIG. **5**. The strain gauge elements A**2** and A**1** are disposed on the other end of the strain-flexing part body **50** at positions not contacting the crank arm **20***a*.

The strain gauge element A**1** disposed on a third side **66***c* between the first side **66***a* and the second side **66***b* of the Wheatstone bridge circuit **66** and the strain gauge element A**3** disposed on a fourth side **66***d* between the first side **66***a* and the second side **66***b* are disposed on the one end (in FIG. **5**, the left end) of the strain-flexing part **22**. The strain gauge elements A**1** and A**3** are disposed on the one end of the strain-flexing part body **50** at positions not contacting the crank arm **20***a*.

The two strain gauge elements A**1** and A**3** are symmetrically disposed with respect to the longitudinal neutral axis CX of the strain-flexing part **22** at the one end of the strain-flexing part **22**. The two strain gauge elements A**2** and A**4** are symmetrically disposed with respect to the longitudinal neutral axis CX of the strain-flexing part **22** at the other end of the strain-flexing part **22**. The directions in which the strain gauge elements A**1**, A**2**, A**3**, and A**4** detect strain are disposed along the longitudinal direction of the crank arm **20***a*. The strain gauge element A**1** and the strain gauge element A**2** are disposed to one side of the longitudinal neutral axis CX of the strain-flexing part **22** in a direction orthogonal to the longitudinal direction of the crank arm **20***a*. The strain gauge element A**3** and the strain gauge element A**4** are disposed to the other side of the longitudinal neutral axis CX of the

strain-flexing part **22** in the direction orthogonal to the longitudinal direction of the crank arm **20***a*.

As shown in FIG. **4**, the four strain gauge elements T**1**, T**2**, T**3**, and T**4** constituting the fourth strain sensor **60** are disposed substantially at a central part CP in the longitudinal direction of the strain-flexing part **22**. The central part CP encompasses the center and the vicinity of the center. The strain gauge elements T**1** T**2**, T**3**, and T**4** are disposed in the central part longitudinal direction of the strain-flexing part body **50**. The strain gauge element T**2** and the strain gauge element T**1** disposed on an adjacent first side **68***a* and third side **68***c* of the four sides of the Wheatstone bridge circuit **68** in the fourth strain sensor **60**, as shown in FIG. **10**, are disposed on the fourth surface **52***d*, as shown in FIG. **4**. As shown in FIG. **5**, the strain gauge element T**4** disposed on a second side **68***b* facing the first side **68***a* and the strain gauge element T**3** disposed on a fourth side **68***d* facing the third side **68***c* are disposed on the first surface **52***a*.

The two strain gauge elements T**3** and T**4** disposed on the first surface **52***a* are symmetrically disposed with respect to the longitudinal neutral axis CX of the strain-flexing part **22**. The two strain gauge elements T**1** and T**2** disposed on the fourth surface **52***d* are also symmetrically disposed with respect to the longitudinal neutral axis CX of the strain-flexing part **22**. In other words, in the fourth strain sensor **60**, two strain gauge elements disposed on the same surface are symmetrically disposed with respect to the longitudinal neutral axis CX of the strain-flexing part **22**.

The strain gauge element T**1** is disposed so that the direction in which it detects strain is tilted 45° with respect to the longitudinal direction of the crank arm **20***a*. The strain gauge element T**2** is disposed so that the direction in which it detects strain is tilted 45° with respect to the longitudinal direction of the crank arm **20***a* and orthogonal to the direction in which the strain gauge element T**1** detects strain.

The strain gauge element T**3** is disposed so that the direction in which it detects strain is tilted 45° with respect to the longitudinal direction of the crank arm **20***a* and substantially parallel to the direction in which the strain gauge element T**2** detects strain. The strain gauge element T**4** is disposed so that the direction in which it detects strain is tilted 45° with respect to the longitudinal direction of the crank arm **20***a*, orthogonal to the direction in which the strain gauge element T**2** detects stress, and substantially parallel to the direction in which the strain gauge element detects strain.

The strain gauge element T**1** and the strain gauge element T**4** are disposed at overlapping positions sandwiching the strain-flexing part body **50**. The strain gauge element T**2** and the strain gauge element T**3** are also disposed at overlapping positions sandwiching the strain-flexing part body **50**.

The strain gauge elements T**1**, T**2**, T**3**, and T**4** of the fourth strain sensor **60** may also be all disposed on the first surface **52***a* or the fourth surface **52***d*, as shown in FIG. **19**. The strain gauge element T**2** disposed on a first side **68***a* of the Wheatstone bridge circuit **68** and the strain gauge element T**1** disposed on a third side **68***c*, and the strain gauge element T**4** disposed on a second side **68***b* and the strain gauge element T**3** disposed on a fourth side **68***d*, are symmetrically disposed with respect to the longitudinal neutral axis CX of the strain-flexing part **22**. The strain gauge element T**1** and the strain gauge element T**2** are symmetrically disposed on either side of the center of the longitudinal direction of the strain-flexing part **22**, and the strain gauge element T**3** and the strain gauge element T**4** are disposed symmetrically on either side of the longitudinal direction of the strain-flexing part **22**.

The interference suppression part **26** suppresses interference from, for example, a third force component Fz within the second force component Fr detected by the second strain sensor **56**. The interference suppression part **26** has a first interference suppression part **70**, as shown in FIG. **11**, for suppressing interference via a computational process, and a second interference suppression part **72**, as shown in FIG. **3**, for suppressing interference via the structure of the strain-flexing part **22**.

The first interference suppression part **70** is realized by a computing processor **76** including a microcomputer executing software. The computing processor **76** may be contained within an indentation or other containment space formed in the first crank arm **20***a* and the second crank arm **20***b*, or may be housed in a case member **74** optionally provided on a side surface of the second crank arm **20***b*, as shown in FIG. **1**. In the present embodiment, the computing processor **76** is provided within a case member **74**.

The computing processor **76** is connected to the first strain sensor **54**, second strain sensor **56**, third strain sensor **58**, and fourth strain sensor **60** provided on the first crank arm **20***a* and the second crank arm **20***b*. The computing processor **76** and the strain sensors **54**, **56**, **58**, and **60** are electrically connected by a line such as an electrical cable, printed wiring, or the like. The computing processor **76** and the strain sensors **54**, **56**, **58**, and **60** may also be connected over a signal-amplifying relay circuit. In the present embodiment, the computing processor **76** is provided within the case member **74**; thus a wire for connecting the strain sensors **54**, **56**, **58**, and **60** of the first crank arm **20***a* and the computing processor **76** is provided on the crank shaft **12**. Holes (not illustrated) through which wires can be passed are provided, as appropriate, in the first crank arm **20***a*, the second crank arm **20***b*, and the crank shaft **12**.

The computing processor **76** is provided on the first crank arm **20***a*, and a cadence sensor **78** for measuring the rotational speed of the first crank arm **20***a* is connected thereto. The cadence sensor **78** may also be provided on an arm of the sprocket attachment part **75**. The cadence sensor **78** is manifested by, for example, a lead switch. The computing processor **76** is further connected to a cadence sensor **78**, provided on the second crank arm **20***b*, for measuring the rotational speed of the second crank arm **20***b*, a power source **71** constituted by a battery, and a wireless communication unit **73** capable of transmitting computed data to an external device, such as a personal computer. The power source **71** is provided on one of an indentation or other containment space formed in the first crank arm **20***a* or the second crank arm **20***b*, the crank shaft **12**, or the case member **74**. The cadence sensor **78** is faceably disposed with respect to at least one magnet provided on the frame of the bicycle on the periphery of the crank shaft **12**.

The wireless communication unit **73** is provided in the case member **74**. The case member **74** is formed from a synthetic resin that does not block radio waves. The case member **74** is detachably or undetachably anchored to the second crank arm **20***b* using anchoring means such as a bolt, an adhesive, or a band. The case member **74** is preferably attached to a side surface of the second crank arm **20***b* facing the bicycle frame when the crank assembly **10** is attached to a bicycle.

The first interference suppression part **70** has a first force component calculator **80**, a load position calculator **82**, a second force component calculator **84**, and a third force component calculator **86** as software-manifested functional features. The second force component calculator **84** has an interference component calculator **88** and an interference component eliminator **90**.

The output OP**1** (Fθ) of the first strain sensor **54** corresponds to the bending moment M (Fθ) in the rotational direction of the first crank arm **20***a*. Thus, as shown in FIG. **3**, the

bending moment M (Fθ) of the first strain sensor **54** is the product of the first force component Fθ and a distance L**1** (Fθ×L**1**). Here, the distance L**1** is the distance between a central position of the longitudinal direction of the four strain gauge elements B**1**-B**4** of the first strain sensor **54** and the axial center of the first pedal **16***a*. Thus, the first three component calculator **80** divides the bending moment M (Fθ) of the first strain sensor **54** by the distance L**1** to calculate the first force component Fθ. That is, Fθ=OP**1**=M(Fθ)/L**1**.

The output OP**4** (=L) of the fourth strain sensor **60** corresponds to the torque T(Fθ) of the first force component Fθ of the load position L; thus, as shown in FIG. **3**, the torque T(Fθ) is the product of the first force component Fθ and the load position L (Fθ×L). Thus, the load position calculator **82** divides the output OP**4** of the fourth strain sensor **60** by the first force component Fθ to calculate the load position L. That is, L=OP**4**=T(Fθ)/Fθ.

The output OP**2** (Fr') of the second strain sensor **56** corresponds to the Fr bending moment M (Fr') of the load position L. The output OP**2** (Fr') can be found by dividing the bending moment M (Fr') of the second strain sensor by the load position L. That is, Fr=OP**2**=M(Fr')/L.

The output OP**3** (Fz) of the third strain sensor **58** corresponds to the bending moment M(Fz) of the first crank arm **20***a*. The bending moment M(Fz) of the third strain sensor **58** is a product of the third force component Fz and a distance L**2** obtained by subtracting a distance L**3** from the strain gauge elements A**1**, A**3** on the one end to the axial center of the first pedal **16***a* from a distance L**4** from the gauge elements A**2**, A**4** on the other end as shown in FIG. **3** to the axial center of the first pedal **16***a*. Thus, the third force component calculator **86** divides by the output OP**3** bending moment M(Fz) of the third strain sensor **58** to calculate the third force component Fz. That is, Fz=OP**3**=M(Fz)/L**2**.

In the second force component calculator **84**, the interference component calculator **88** calculates the Fz interference component of the third force component upon the output OP**2** of the second strain sensor **56**. The interference component IF of the third force component Fz upon the second strain sensor **56** is the moment of a distance L**5** from the second strain sensor **56** of the third force component Fz to the axial center of the first pedal **16***a*. Thus, the interference component calculator **88** calculates Fz×L**5**, the product of the calculated third force component Fz and the distance L**5**. That is, IF=Fz×L**5**.

The interference component eliminator **90** of the second force component calculator **84** eliminates the interference component IF of the third force component Fz in the bending moment M(Fr') of the second strain sensor **56**. Specifically, the interference component Fz×L**5** constituting the product of the third force component Fz calculated by the third force component calculator **86** and the distance L**5** is subtracted from the output OP**2** of the second strain sensor **56** to find the moment M(Fr) of the true second force component Fr, and this moment is divided by the load position L to calculate the true second force component Fr. That is, Fr=(M(Fr')−IF)/L. It is thereby possible to suppress interference from the third force component Fz.

The relationship between the outputs of the various sensors, the various first force components, and the load position can be experimentally determined in advance. Thus, the outputs of the sensors are treated as the force components and the load position in the foregoing description.

The second interference suppression part **72** suppresses interference from the second force component Fr upon the output OP**3** of the second strain sensor **56** via the structure of the strain-flexing part **22**. As shown in FIG. **3**, the second interference suppression part **72** is formed displaced from a central position in the longitudinal direction of the first crank arm **20***a* toward the one end of the strain-flexing part **22**, that is, toward the pedal attachment part **34***a*. The second interference suppression part **72** is formed in the strain-flexing part body **50**. The area of a cross section orthogonal to the longitudinal direction of the second interference suppression part **72** differs from that in other parts of the strain-flexing part body **50**, and, in the present embodiment, the area of the cross section differs from that in other parts of the strain-flexing part body **50**. In the first embodiment, the second interference suppression part **72** is constituted by forming a through-hole **72***a*. As shown in FIG. **6**, the through-hole **72***a* is formed penetrating the second surface **52***b* and the third surface **52***c*. The second interference suppression part **72** is disposed near the second strain sensor **56**. The cross section of the through-hole **72***a* perpendicular to the direction in which the hole extends may be perfectly round, elongated, ellipsoidal, or polygonal.

In the present embodiment, the interference component IF within the second force component Fr is suppressed by the first interference suppression part **70** and the second interference suppression part **72**, allowing for precise measurement of the second force component Fr. When, for example, a load was placed on the first crank arm **20***a* in a simulation, interference was −165% when no interference suppression part **26** was provided, but was reduced to −2.3% when an interference suppression part **26** was provided. Here, interference is a percentage obtained by dividing the second force component (Fr) measured from the output of the third strain sensor **58** when a predetermined load acts in the tension direction of the first crank arm **20***a* and the output of the third strain sensor **58** when a predetermined load acts in the axial direction of the pedal shaft by the measured third force component (Fz).

The measured results are transmitted to an external device by the wireless communication unit **73**. FIG. **12** shows an example of the various force component load positions and the crank rotational speed being displayed on the external device.

In FIG. **12**, when a bicycle to which the crank assembly **10** provided with the first pedaling force measurement device **14***a* and the second pedaling force measurement device **14***b* is mounted is driven, or a rotational load device for applying a rotational load to the rotation of the rear wheel of the bicycle is set and the bicycle is pedaled, the following display is shown based on the measured three force components, the load position, the crank rotational speed, and the like.

Results 1. three-dimensional pedaling efficiency, 2. power, 3. maximum power, 4. maximum speed, 5. crank rotational speed, 6. pulse, and 7. measurement time are shown in order from the top of the display screen. Numerical values for 8. power and 9. three-dimensional pedaling efficiency are shown therebelow for the left and right feet. Below that, graphs for 10. average load position, 11. average load position deviation, 12. backpedaling efficiency, 13. peak torque crank angle, and 14. average pedaling pattern are shown. Users can thereby learn the pedaling methods that are optimal for the, or select an optimal crank length.

1. Three-dimensional pedaling efficiency D, 9. Left crank three-dimensional pedaling efficiency DL, and right crank three-dimensional pedaling efficiency DR are calculated, for example, according to the formula shown in FIG. **20**. Percentages obtained by multiplying the calculated values by 100 are displayed on the screen.

2. Power and 8. Left crank power and right crank power are found by multiplying the rotational torque and the number of rotations of the crank arm. The rotational torque of the crank

arm is found using the first force component Fθ and the length of the crank arm. Information regarding the length of the crank arm may be stored in the computing processor, or may be set in the external device. The number of rotations is a value obtained from the cadence sensor **78**. The product of the left crank power and the right crank power is displayed as power.

3. Maximum power is the value for power when it reaches maximum.

4. Maximum speed is the value for speed when it reaches maximum. For speed, information may be obtained from a typical speedometer provided on the bicycle, or the computing processor **76** may calculate speed on the basis of the cadence, gear ratio, and tire diameter. In this case, gear ratio information is received by the wireless communication unit **73**, tire diameter information is set in advance.

5. Crank rotational speed is calculated on the basis of the cadence sensor **78**.

6. Pulse is information transmitted by wireless or other means from a heart rate sensor when the rider is wearing a heart rate sensor.

7. Measurement time is the length of time for which measurement was performed. Instructions to begin and end measurement are given, for example, by the external device.

10. Average load position is the average value for the load position L measured at constant intervals during the measurement time. The average load position is displayed along with a graphic representing the pedal, as a triangle (∇) layered over the graphic representing the pedal. A scatter plot for load position is displayed beneath the graphic showing the average load position. A range of motion bar showing the range of the motion of the load position is also displayed over the graphic representing the pedal.

11. Average load position deviation is the average load position deviation from a central position of the pedal. The central position of the pedal is preset in the external device.

12. Backpedaling efficiency is displayed along with a graphic representing the crank arm, and indicates the proportions of force being applied in the forward rotational direction and the reverse rotational direction of the crank arm. For example, in FIG. **12**, the proportion of force being applied in the forward rotational direction of the right crank arm is 96%, and the proportion of force being applied in the reverse rotational direction is 4%.

13. Peak torque crank angle indicates the crank angle is torque is at maximum. The crank angle when torque is at maximum is calculated on the basis of information from the cadence sensor.

14. Average pedaling pattern is a composite vector Fθ and Fr.

Second Embodiment

In the first embodiment, the present invention was described using an example of a crank arm having a constant crank length, but, in a second embodiment, the present invention will be described using an example of a crank arm having a variable crank length.

As shown in FIG. **13**, a second pedaling force measurement device **114***a* is provided toward the front side of the drawing in the second embodiment.

A crank assembly **110** used in the second embodiment of the present invention is provided with a crank shaft **112**, configured similarly to that of the first embodiment, having a first end **112***a* and a second end **112***b*, a first pedaling force measurement device **114***a*, a second pedaling force measurement device **114***b*, and a sprocket **115**. A cadence sensor **78** is provided on a surface of a first crank arm **120***a* upon which the sprocket **115** is provided facing a second crank arm **120***b*. A cadence sensor **78** is similarly provided on a surface of the second crank arm **120***b* facing the first crank arm **120***a*. The first pedaling force measurement device **114***a* is coupled to the first end **112***a* of the crank shaft **112** so as to be capable of rotating integrally with the crank shaft **112**. The second pedaling force measurement device **114***b* is coupled to the second end **112***b* of the crank shaft **112** so as to be capable of rotating integrally with the crank shaft **112**. Here, the first end **112***a* of the crank shaft **112** is disposed to the right side of a bicycle as seen from behind when the crank assembly **110** is mounted on the bicycle, and the second end **112***b* is disposed to the left side.

The first pedaling force measurement device **114***a* has a first crank arm **120***a*, a strain-flexing part, a parameter detection part, and an interference suppression part. The second pedaling three measurement device **114***b* has a second crank arm **120***b*, a strain-flexing part, a parameter detection part, and an interference suppression part. The configurations of the strain-flexing part, parameter detection part, and interference suppression part are similar to those of the first embodiment, and description thereof will therefore be omitted. The following description will described the second crank arm **120***b* of the second pedaling force measurement device **114***b*, and those parts of the first crank arm **120***a* differing from the second crank arm **120***b*.

The second crank arm **120***b*, which is disposed toward the front of the drawing in FIG. **13**, is provided with a second pedal attachment part **134***b*, a second crank shaft attachment part **136***b*, and a second crank length adjustment mechanism **138***b*, as shown in FIG. **14**.

The second pedal attachment part **134***b* has a pedal attachment hole **135***b* in which a female screw part for attaching the second pedal is formed. A housing indentation **138***b* in which the strain-flexing part **122** can be housed is formed in the interior of the second pedal attachment part **134***b*. The housing indentation **138***b* is formed as a rectangular indentation in the other end surface **134***c* of the second pedal attachment part **134***b*. The housing indentation **138***b* is closed off by a cap member, not shown in the drawing, mounted on the other end surface **134***c*. The strain-flexing part **122** is anchored to a twenty-first housing indentation **138***b* by four anchoring bolts **142**.

A case member similar to that of the first embodiment is provided on the second pedal attachment part **134***b*, and a computing processor **76** and a wireless communication unit are contained within the case member. As in the previous embodiment, the computing processor **76**, the first crank arm **120***a*, the second crank arm **120***b*, and the various strain sensors are connected by a line such as an electrical cable, printed wiring, or the like. A space for internally disposing the line is provided in the second crank shaft attachment part **136***b*; in the present embodiment, the cadence sensor **78** is also provided in this space.

A space for internally disposing the line is provided in the second crank shaft attachment part **136***b*. A space for internally disposing the line is also provided in one second guide shaft **191***b*. A hole connecting the hollow space within the crank shaft and the space provided inside the second crank shaft attachment part **136***b* is formed at the part where the second crank shaft attachment part **136***b* and the crank shaft **112** contact. A hole connecting the space provided inside in the second crank shaft attachment part **136***b* and the space provided in the one second guide shaft **191***b* is also formed at the part where the second crank shaft attachment part **136***b* and the second guide shaft **191***b* contact. A hole connecting

the space funned in the one second guide shaft **191***b* and the housing hole formed by the housing indentation **138** is further formed at the part where the second guide shaft **191***b* and the second pedal attachment part **134***b* contact.

The line passing through the hollow part of the crank shaft **112** is drawn around the second pedal attachment part **134***b* through the space formed in the second crank shaft attachment part **136***b* of the second crank arm **120***b* and one of the spaces formed in the interior of the second guide shaft **191***b*. The first crank arm **120***a* is similarly configured; thus, description thereof will be omitted.

The second crank shaft attachment part **1361**) has a serrated second attachment hole **137***b* in which a slit **137***c* is formed. A first slit **137***c* extends in a radial direction from the second attachment hole **137***b* to the outer surface of the second crank shaft attachment part **136***b*. The width of the first slit **137***c* is reduced by a tightening bolt **146***b* inserted from a direction intersecting the first slit **137***c*. The second crank arm **120***b* is thereby anchored to the second end **112***b* of the crank shaft **112**. A second hole **137***d* for anchoring a first crank shaft attachment part **136***b* in the longitudinal direction formed on both ends in a direction orthogonal to the longitudinal direction in the second crank shaft attachment part **136***b*. A second slit **137***e* (see FIG. **13**) is formed at the part formed by the second hole **137***d*. A bolt member **145** for anchoring the second crank shaft attachment part **136***b* screws into the second hole **137***d*.

The second crank length adjustment mechanism **138***b* is a mechanism capable of altering the relative positions of the second pedal attachment part **134***b* and the second crank shaft attachment part **136***b* in the lengthwise direction of the second crank arm **120***b*. The second crank length adjustment mechanism **138***b* has a pair of second guide shafts **191***b*, a pair of second guide holes **192***b*, and a second positioning mechanism **193***b*.

The pair of second guide shafts **191***b* are provided on the other end surface of the second pedal attachment part **134***b* separated from each other in a direction orthogonal to the lengthwise direction, and are anchored to the other end surface via, for example, press-fitting. The pair of second guide holes **192***b* are provided in the second crank shaft attachment part **136***b*, thereby guiding the second crank shaft attachment part **136***b* to the second guide shaft **191***b*.

The second positioning mechanism **193***b* has a rack **194***b* anchored to one of the pair of second guide shafts **191***b* and a claw member **195***b* engaging with the rack **194***b*. As shown in FIGS. **15** and **16**, the rack **194***b* is disposed extending in the lengthwise direction, and is anchored to the outer surface of the second guide shaft **191***b*. The engagement pitch of the rack **194***b* and the claw member **195***b* is preferably set to 2.5 mm. The adjustable range for the total length of the crank arm is set, for example, to from 155 tarn to 180 mm.

The claw member **195***b* has a claw **195***c* for engaging with the rack **194***b* and a compression operation part **195***d* exposed on the outer surface of the crank shaft attachment part **136***b*. The claw member **195***b* is capable of moving to an engagement position, shown in FIG. **16**, at which the claw **195***c* engages with the rack **194***b*, and a release position, shown in FIG. **15**, at which the engagement with the rack **194***b* is released via a compressive operation by the compression operation part **195***d*. The claw member **195***b* is guided to the engagement position and the release position by a guide member **196** provided on the second crank shaft attachment part **136***b*. As shown in FIG. **15**, the claw member **195***b* is biased toward the engagement position by a biasing member **197** in the form of, for example, a coil spring. A positioning projection **195***e* contacting the rack **194***b* at the engagement position is provided on the claw **195***c*.

Using a second positioning mechanism **193***b* so configured, when the bolt member **145** is loosened and the compression operation part **195***d* is pressed to move the claw member **195***b* to the release position, the engagement of the claw member **195***b* and the rack **194***b* is released, and the second crank shaft attachment part **136***b* becomes capable of moving with respect to the second pedal attachment part **134***b* in the lengthwise direction. When the second crank shaft attachment part **136***b* is moved to a desired crank length, the compression operation part **195***d* is released. When the user's hand is removed from the compression operation part **195***d*, the biasing member **197** returns the claw member **195***b* to the engagement position. Finally, two bolt members **145** are tightened to complete the process of adjusting the crank arm. It is thereby possible to adjust the length of the second crank arm **120***b*, allowing a crank length that is optimal for the user to be obtained.

For the first crank arm **120***a*, the crank shaft attachment part, not shown in the drawing, is not anchored by the tightening bolt **146***b* to the crank shaft **112** of the first slit **137***c*; rather, the first end **112***a* of the crank shaft **112** is anchored via press-fitting or bonding. All other features are similar to those of the second crank arm **120***b*, and the length of the first crank arm **120***a* can be adjusted in a similar manner.

For the second crank arm **120***b* of the present embodiment, the longitudinal direction length of the second crank arm **120***b* can be adjusted simply by loosening the bolt member **145** and pressing the compression operation part **195***d*. The user is thus capable of adjusting the length of the crank arm via a simple operation. Because a rack **194***b* and claw member **195***b* are used as a positioning mechanism, fine adjustments in length can be made as needed.

Other Embodiments

(a) In the embodiments described above, the strain-flexing part is provided separately from the first crank arm. However, in a first pedaling force measurement device **214***a*, it is also acceptable for the strain-flexing part to be formed integrally with a first crank arm **220***a*, as a one-piece, unitary member as shown in FIG. **17**. In other words, in FIG. **17**, the first pedaling force measurement device **214***a* is a non-removable part of the first crank arm **220***a*. In FIG. **17**, strain gauge elements constituted by a first strain sensor **254**, a second strain sensor **256**, a third strain sensor **258**, and a fourth strain sensor **260** are applied to the outer surface of a first crank arm **220***a*. However, in the case of a hollow crank arm—for example, a bisected crank arm—strain gauge elements may also be applied to an inner surface of the crank arm.

(b) The strain gauge elements constituting the strain sensors are not limited to thin-film, capacitive, or semiconductor types; any type capable of detecting strain in the crank arm or strain-flexing part is acceptable.

(c) In the embodiments described above, the strain-flexing part body is constituted by a quadrangular prism, but the present invention is not limited to such. Any shape is possible as long as it has, for example, at least two orthogonally disposed surfaces. For example, the strain-flexing part body may be a square pipe or an octagonal prism. Moreover, the strain-flexing part body may also be a member having a cross section orthogonal to the lengthwise direction that is T-shaped, I-shaped, H-shaped, or U-shaped, and extending in the longitudinal direction.

(d) In the embodiment described above, the present invention has been described using an example of a pedaling force

measurement device for a bicycle, but the present invention is not limited to such. For example, the present invention can also be applied to exercise devices having a crank arm to which pedals or other operational parts can be attached for the purpose of maintaining or increasing physical strength, such as an exercise bike.

(e) In the embodiments described above, the interference suppression part comprises both a first interference suppression part for computationally suppressing interference by computing detected values for the strain sensors and a second interference suppression part for physically suppressing interference, but the present invention is not limited to such. A configuration provided with at least one of the first interference suppression part and the second interference suppression part as a pedaling force measurement device is acceptable.

(f) In the embodiments described above, the strain sensors are constituted by four strain gauge elements apiece so as to perform temperature compensation, but, if temperature compensation is not necessary, it is also acceptable for the strain sensors to be constituted by two strain gauge elements apiece. In such cases, temperature compensation may be performed using a different sensor, such as a temperature sensor.

(g) In the embodiments described above, the first crank arm **20***a* is a constituent feature of the first pedaling force measurement device **14***a*, but the first crank arm **20***a* need not be a constituent feature of the first pedaling force measurement device **14***a*.

(h) In the embodiments described above, the strain-flexing part **22** is detachably provided on the first crank arm **20***a*, but the strain-flexing part **22** may also be undetachably anchored to the first crank arm **20***a* using an adhesive or the like.

(i) In the embodiments described above, the first cover **43***a* is provided from the one end **31***a***1** of the first crank arm **20***a* in the longitudinal direction to an other end **31***a* so as to entirely cover one side of the first arm body **30***a*, but it is also acceptable for the first cover **43***a* to cover only the first housing part **38***a*.

(j) In the embodiments described above, the anchoring holes **40***a* are formed as screw holes, but the anchoring holes **40***a* may also be through-holes. In such cases, the anchoring holes **51***a* of the anchor portions **51** need only be formed as screw holes, and the first arm body **30***a* be sandwiched between the heads of the bolts and the anchor portions **51**.

(k) In the first embodiment, an opening is formed in the direction opposite the bicycle in the direction in which the crank shaft extends when the crank assembly **10** is attached to a bicycle, but it is also acceptable for the first housing part **38***a* to open towards the bicycle.

It is also acceptable thr the first housing part **38***a* to open facing upstream or downstream in the rotational direction of the first crank arm **20***a*; that is, in either of the longitudinal direction of the crank arm and a direction perpendicular to the pedal shaft. In such cases, the first housing part **38***a* need only be anchored to the strain-flexing part **22** via a method similar to that of the second embodiment.

(l) In the embodiments described above, cadence sensors are provided on each of the crank arms, but it is also acceptable for a cadence sensor to be provided on only one of the crank arms. It is also acceptable to provide the crank arm with a sensor for detecting the rotational position of the crank arm instead of a cadence sensor.

(m) In the embodiments described above, one each of a computing processor, a wireless communication unit, and a power source are provided, but it is also acceptable to provide a computing processor, a wireless communication unit, and a power source on each of the crank arms.

(n) In the second embodiment, it is preferable to use a separate spring member, ball plunger mechanism, or the like to bias the claw **195***c* toward the rack **194***b*, thereby allowing the user to feel clicks when adjusting length. In such cases, it is acceptable to provide the claw member **195***b* which a ball plunger mechanism directly engaging with the rack **194***b* instead of using a separate biasing mechanism to bias the claw **195***c* toward the rack **194***b*.

(o) In the second embodiment, the rack **194***b* is a separate member anchored to the second guide shaft **191***b*, but the present invention is not limited to such. For example, it is also acceptable to directly form a plurality of grooves in the surface of the second guide shaft **191***b*, forming the rack **194***b* integrally with the second guide shaft **191***b*.

(p) In the second embodiment, a bolt member **145** is used to finally anchor the crank arm length, but the present invention is not limited to such. For example, a click-release mechanism used to attach to and detach from the frame of the bicycle wheel may be used instead of a bolt member.

While only selected embodiments have been chosen to illustrate the present invention, it will be apparent to those skilled in the art from this disclosure that various changes and modifications can be made herein without departing from the scope of the invention as defined in the appended claims. In particular, the various embodiments and modifications described in the present specification can be arbitrarily combined as necessary. Thus, the foregoing descriptions of the embodiments according to the present invention are provided for illustration only, and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

What is claimed is:

1. A pedaling force measurement device for measuring a plurality of parameters of pedaling force acting on a crank arm, the pedaling force measurement device comprising:

a strain-flexing part configured to receive a strain acting on the crank arm from pedaling, the strain-flexing part being disposed entirely on the crank arm;

a parameter detection part disposed on the strain-flexing part to detect the parameters from the strain acting on the strain-flexing part; and

an interference suppression part configured to suppress interference from one parameter detected by the parameter detection part from other ones of the parameters.

2. The pedaling force measurement device according to claim **1**, wherein

the parameter detection part comprises:

a second strain sensor configured to detect a second force component, corresponding to a crank arm longitudinal force component of a bending moment due to a load acting upon the crank arm from pedaling, as one of the parameters; and

a third strain sensor configured to detect a third force component, corresponding to a pedal axial direction force component of the bending moment due to the load acting upon the crank arm from pedaling, as one of the parameters.

3. The pedal force measurement device according to claim **2**, wherein

the parameter detection part comprises:

a first strain sensor configured to detect a first force component, corresponding to a rotational direction force component of the bending moment due to the load acting upon the crank arm from pedaling, as one of the parameters; and

a fourth strain sensor configured to detect a fourth force component, corresponding to a shear force the load

acting upon the crank arm, as one of the parameters to determine an axial direction load position from pedaling.

4. The pedaling force measurement device according to claim **3**, wherein

each of the first through fourth strain sensors comprises at least vo strain gauge elements forming a Wheatstone bridge circuit.

5. The pedaling force measurement device according to claim **3**, wherein

each of the first through fourth strain sensors comprises four strain gauge elements forming a Wheatstone bridge circuit.

6. The pedaling force measurement device according to claim **5**, wherein

the strain-flexing part has a first surface, a second surface, a third surface and a fourth surface extending in a longitudinal direction of the crank arm;

the first surface and the fourth surface are substantially perpendicular to a shaft of the pedal; and

the second surface and the third surface are substantially parallel to the shaft of the pedal.

7. The pedaling force measurement device according to claim **6**, wherein

the strain-flexing part comprises a quadrangular prism.

8. The pedaling force measurement device according to claim **6**, wherein

the four strain gauge elements forming the third strain sensor are disposed on one of the first and fourth surfaces of the strain-flexing part;

the Wheatstone bridge circuit of the third strain sensor has a first pair of oppositely disposed strain gauge elements of the four strain gauge elements of the third strain sensor and a second pair of oppositely disposed strain gauge elements of the four strain gauge elements of the third strain sensor;

the first pair of oppositely disposed strain gauge elements being spaced from the second pair of oppositely disposed strain gauge elements in the longitudinal direction of the crank arm; and

the first and second pairs of oppositely disposed strain gauge elements being symmetrically disposed with respect to a longitudinal neutral axis of the strain-flexing part.

9. The pedaling force measurement device according to claim **6**, wherein

the four strain gauge elements forming the third strain sensor are disposed on one of the first and fourth surfaces of the strain-flexing part;

the Wheatstone bridge circuit of the third strain sensor has first, second, third and fourth strain gauge elements forming the four strain gauge elements of the third strain sensor;

the first and third strain gauge elements being oppositely disposed from each other in the Wheatstone bridge circuit of the third strain sensor, the second and fourth strain gauge elements being disposed between the first and third strain gauge elements;

the first and third strain gauge elements being symmetrically disposed with respect to a longitudinal neutral axis of the strain-flexing part and disposed at one end of the strain-flexing part; and

the second and fourth strain gauge elements being symmetrically disposed with respect to the longitudinal neutral axis of the strain-flexing part and disposed at the other end of the strain-flexing part.

10. The pedaling force measurement device according to claim **6**, wherein

the four strain gauge elements forming the first strain sensor are disposed on one end of the strain-flexing part;

the Wheatstone bridge circuit of the first strain sensor has first, second, third and fourth strain gauge elements forming the four strain gauge elements of the first strain sensor;

the first and third strain gauge elements being oppositely disposed from each other in the Wheatstone bridge circuit of the first strain sensor, the second and fourth strain gauge elements being disposed between the first and third strain gauge elements;

the first and third strain gauge elements being disposed on one of the second and third surfaces, while the second and fourth strain gauge elements being disposed on the other of the second and third surfaces;

the first and third strain gauge elements being symmetrically disposed with respect to a longitudinal neutral axis of the strain-flexing part; and

the second and fourth strain gauge elements being symmetrically disposed with respect to the longitudinal neutral axis of the strain-flexing part.

11. The pedaling force measurement device according to claim **6**, wherein

the four strain gauge elements forming the first strain sensor are disposed on one end of the strain-flexing part;

the Wheatstone bridge circuit of the first strain sensor has first, second, third and fourth strain gauge elements forming the four strain gauge elements of the first strain sensor;

the first and third strain gauge elements being oppositely disposed from each other in the Wheatstone bridge circuit of the first strain sensor, the second and fourth strain gauge elements being disposed between the first and third strain gauge elements;

the first and third strain gauge elements being disposed on one of the second and third surfaces, while the second and fourth strain gauge elements being disposed on the other of the second and third surfaces;

the first and third strain gauge elements being aligned in the longitudinal direction of the strain-flexing part; and

the second and fourth strain gauge elements being aligned in the longitudinal direction of the strain-flexing part.

12. The pedaling force measurement device according to claim **6**, wherein

the four strain gauge elements forming the second strain sensor are disposed on one end of the strain-flexing part;

the Wheatstone bridge circuit of the first strain sensor has first, second, third and fourth strain gauge elements forming the four strain gauge elements of the second strain sensor;

the first and third strain gauge elements being oppositely disposed from each other in the Wheatstone bridge circuit of the second strain sensor, the second and fourth strain gauge elements being disposed between the first and third strain gauge elements;

the first and third strain gauge elements being disposed on one of the first and fourth surfaces, while the second and fourth strain gauge elements being disposed on the other of the first and fourth surfaces;

the first and third strain gauge elements being symmetrically disposed with respect to a longitudinal neutral axis of the strain-flexing part; and

the second and fourth strain gauge elements being symmetrically disposed with respect to the longitudinal neutral axis of the strain-flexing part.

13. The pedaling force measurement device according to claim 6, wherein

the four strain gauge elements forming the fourth strain sensor are disposed at a center area of the strain-flexing part with respect to the longitudinal direction of the strain-flexing part;

the Wheatstone bridge circuit of the first strain sensor has first, second, third and fourth strain gauge elements forming the four strain gauge elements of the fourth strain sensor;

the first and third strain gauge elements being oppositely disposed from each other in the Wheatstone bridge circuit of the fourth strain sensor, the second and fourth strain gauge elements being disposed between the first and third strain gauge elements;

the first and second strain gauge elements being disposed on one of the first and fourth surfaces, while the third and fourth strain gauge elements being disposed on the other of the first and fourth surfaces;

the first and second strain gauge elements being symmetrically disposed with respect to a longitudinal neutral axis of the strain-flexing part; and

the third and fourth strain gauge elements being symmetrically disposed with respect to the longitudinal neutral axis of the strain-flexing part.

14. The pedaling force measurement device according to claim 6, wherein

the four strain gauge elements forming the fourth strain sensor are disposed at a center of the strain-flexing part with respect to the longitudinal direction of the strain-flexing part;

the Wheatstone bridge circuit of the first strain sensor has first, second, third and fourth strain gauge elements forming the four strain gauge elements of the fourth strain sensor;

the first and third strain gauge elements being oppositely disposed from each other in the Wheatstone bridge circuit of the fourth strain sensor, the second and fourth strain gauge elements being disposed between the first and third strain gauge elements;

the first, second, third and fourth strain gauge elements being disposed on one of the first and fourth surfaces;

the first and second strain gauge elements being symmetrically disposed with respect to a longitudinal neutral axis of the strain-flexing part; and

the third and fourth strain gauge elements being symmetrically disposed with respect to the longitudinal neutral axis of the strain-flexing part.

15. The pedaling force measurement device according to claim 1, wherein

the interference suppression part is formed at a location that is displaced from a central position in a longitudinal direction of the crank arm towards a pedal mounting end of the strain-flexing part, and an area of the location of the interference suppression part has a cross section orthogonal to the longitudinal direction that is different than elsewhere along the crank arm.

16. The pedaling force measurement device according claim 15, wherein

the interference suppression part includes a through-hole formed in the strain-flexing part.

17. The pedaling force measurement device according to claim 1, wherein

the strain-flexing part is provided separately from the crank arm.

18. The pedaling force measurement device according to claim 1, further comprising

a crank arm.

19. The pedaling force measurement device according to claim 18, wherein

the strain-flexing part is integrally formed with the crank arm.

20. A pedaling force measurement device for measuring a plurality of parameters of pedaling force acting on a crank arm, the pedaling force measurement device comprising:

a strain-flexing part configured to receive a strain acting on the crank arm from pedaling;

a parameter detection part disposed on the strain-flexing part to detect the parameters from the strain acting on the strain-flexing part, the parameter detection part comprising

a second strain sensor configured to detect a second force component, corresponding to a crank arm longitudinal force component of a bending moment due to a load acting upon the crank arm from pedaling, as one of the parameters,

a third strain sensor configured to detect a third force component, corresponding to a pedal axial direction force component of the bending moment due to the load acting upon the crank arm from pedaling, as one of the parameters; and

a interference suppression part configured to suppress interference from one parameter detected by the parameter detection part from other ones of the parameters, the interference suppression part being programmed to perform a computational process to suppress interference from the third force component outputted from the third strain sensor while detecting the second force component based on outputs of the second strain sensor.

21. A pedaling force measurement device for measuring a plurality of parameters of pedaling force acting on a crank arm, the pedaling force measurement device comprising:

a strain-flexing part configured to receive a strain acting on the crank arm from pedaling;

a parameter detection part disposed on the strain-flexing part to detect the parameters from the strain acting on the strain-flexing part, the parameter detection part comprising

a first strain sensor configured to detect a first force component, corresponding to a rotational direction force component of the bending moment due to the load acting upon the crank arm from pedaling, as one of the parameters,

a second strain sensor configured to detect a second force component, corresponding to a crank arm longitudinal force component of a bending moment due to a load acting upon the crank arm from pedaling, as one of the parameters,

a third strain sensor configured to detect a third force component, corresponding to a pedal axial direction force component of the bending moment due to the load acting upon the crank arm from pedaling, as one of the parameters, and

a fourth strain sensor configured to detect a fourth force component, corresponding to a shear force the load acting upon the crank arm, as one of the parameters to determine an axial direction load position from pedaling; and

an interference suppression part configured to suppress interference from one parameter detected by the parameter detection part from other ones of the parameters, the interference suppression part being programmed to per-

form a computational process to suppress interference from the third force component based on outputs of the first, second, third and fourth strain sensors.

22. A pedaling force measurement device for measuring a plurality of parameters of pedaling force acting on a crank arm, the pedaling force measurement device comprising:

a crank arm comprising a pedal attachment part for attaching a pedal, a crankshaft attachment part for attaching a crankshaft and a crank length adjustment mechanism adjustably coupling the pedal attachment part to the crankshaft attachment part for altering relative positions of the pedal attachment part and the crankshaft attachment part in a longitudinal direction of the crank arm;

a strain-flexing part configured to receive a strain acting on the crank arm from pedaling;

a parameter detection part disposed on the strain-flexing part to detect the parameters from the strain acting on the strain-flexing part; and

an interference suppression part configured to suppress into interference from one parameter detected by the parameter detection part from other ones of the parameters.

23. The pedaling force measurement device according to claim **22**, wherein

the strain-flexing part is attached to the pedal attachment part.

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